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PHORMIUM TENAX

AS A

FIBROUS PLANT.

BEING SELECTIONS FROM THE REPORTS OF THE COMMISSIONERS APPOINTED BY
THE NEW ZEALAND GOVERNMENT, 1870 TO 1871.

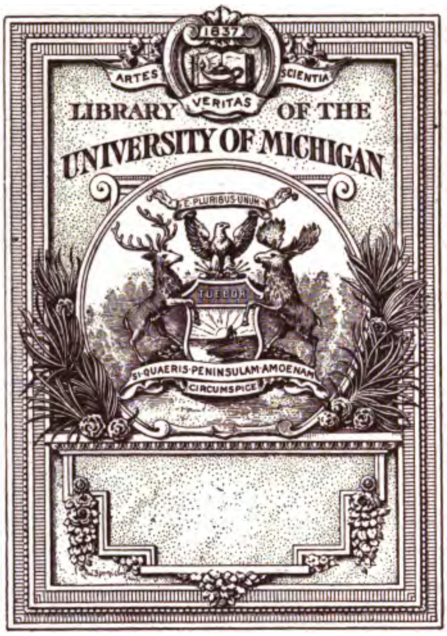
EDITED BY

JAMES HECTOR, M.D., F.R.S.

WITH TWO PLATES.

PUBLISHED BY COMMAND.

WELLINGTON:
PRINTED FOR THE GOVERNMENT OF NEW ZEALAND.
1872.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PREFACE.

THE history of what is usually termed the FLAX INDUSTRY in New Zealand, affords a remarkable instance of the difficulty experienced in developing the natural resources of a country, if the commodities to be disposed of have not a previously established market value.

When the colonists first arrived in New Zealand, the valuable qualities of the *Phormium* fibre were well known, as it was in constant use by the Natives, and a very considerable trade in the article existed as early as 1828, when the islands were only visited by whalers and Sydney traders, as £50,000 worth of the fibre was sold in Sydney alone between 1828 and 1832. At Grimsby, in Lincolnshire, a manufactory was also established in the latter year for the production of articles from New Zealand fibre, which failed from some unexplained cause, notwithstanding that, the results were not considered at the time unsatisfactory.*

From that period up to 1853, the statistics on this subject are very imperfect, but show that a fluctuating trade in the Native dressed fibre was maintained. At the same time many attempts were made in the colony to discover a more speedy and profitable method of preparation. Thus in 1844, a company was formed in England that sent out hand machines and a staff of workmen to the Province of Nelson. The machines proved unsuitable for the purpose, and the enterprise failed. Other machines were then tried, and thousands of pounds were spent in fruitless experiments, simply because the fibre produced did not resemble sufficiently any kind already established in the market, while on the other hand it was not prepared in sufficient quantity to create a position for itself.

From 1853 to 1860 the average annual value of the fibre exported was nearly £2,500, reaching as high as £5,500 in 1855, but up to this time the only fibre exported was that prepared by Native labour, no machinery of any kind being employed in producing the exported article. In 1860, therefore, when the Native disturbances affected the Waikato and other interior districts in the North Island, the preparation was confined to the Native tribes north of Auckland, so that the

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*Jurors Reports N.Z. Ex., p. 113.

160512

average export between 1860 and 1866 was only £150 per annum. It was during this period of depression that attention was most naturally directed to the contrivance of machinery, with the aid of which the fibre could be profitably extracted by European labour.

The attempts up to this time had chiefly been directed to the extraction of the fibre by crushing between rollers, together with boiling in alkaline solutions and through washing,* and all the processes since suggested for the preparation of finer class fibre, have been more or less the same in principle; the improvements being with the view of securing greater rapidity of production, so that a sufficient return could be obtained for the labour employed and the capital sunk in machinery. The first important improvement was that of Messrs. Purchas and Ninnis in 1861, which introduced percussion instead of rolling, and washing without the use of alkaline solutions. This was a most important step, as it first led to the production of the fibre in a state that suited the market, owing to its similarity in appearance to that of Manilla, which was then a well established article of commerce, employed for making what is termed white rope, or rope that will last in water without the protection of tar, and for the manufacture of which a fibre possessing bright lustre and good colour is necessary. The increasing demand for rope of this character, and the limited quantity of Manilla, which fibre depends for its production on Native manual labour in the Phillipine Islands, led to a rise in its value from £21 to £56 per ton, and even to £76 per ton in America during the late civil war. These high prices stimulated the endeavour to introduce *Phormium* fibre to compete with Manilla, and in 1866 the problem of a sufficiently rapid method of producing the fibre from the green leaf was solved by the invention of several machines, in all of which scraping and percussion is applied continuously to the leaf by a drum revolving at such high velocity that the manual labour employed is fully occupied in feeding the leaves and removing the fibre. With these machines the export of fibre again increased, so that from 1866 to 1871 the yearly average was valued at £56,000, the maximum export in that period being £132,578 in 1870. †

This sudden revival of the trade, however, led many to embark in it who were unacquainted, not only with this new form of manufacture, but unaccustomed to any kind of business that required special mechanical skill and careful elaboration of the details of management.

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* Travers, Trans. N.Z. Inst. vol. I. p. 170.

† I am informed by Mr. Seed, Secretary of Customs, that the apparently high value per ton of the fibre exported in 1866, which in Table F. p. 125, is stated at £89, is owing to their having been a large portion of the export entered as "packages," the weight of which was not stated.

The most contradictory opinions prevailed on every subject relating to the manufacture and cultivation of the plant and to the particular requirements of the market, which led to Commissioners being appointed in 1869 and again in 1870 to investigate and report on these matters. The information collected by them will be found at length in a series of reports printed with the parliamentary papers in the years 1870-1, and the following compilation of the more important portions of these reports has been prepared by direction of Government to meet the frequent applications for information on this subject, the supply of extra copies of the official papers having been exhausted.

During the past year the name of New Zealand Flax has been changed to New Zealand Hemp, in the home market, with great advantage to the position which the fibre holds in the brokers' sale rooms; but although the machine dressed fibre at present exported is only applicable to the same purposes as hemp, accounts received since the greater part of this work was in type show that, notwithstanding the contrary opinions that have been expressed, the fibre can be prepared so as to mix advantageously with true *Linum* flax in the manufacture of textile fabrics, and that the shortness of the ultimate fibre is not an insuperable obstacle even to its being spun into unmixed yarns. It will, therefore, in all probability, be necessary to adopt two names for the fibre, to indicate the purpose for which it has been specially prepared, such for instance as *Phormium Hemp* and *Phormium Flax.*

Samples of serge sheeting, canvas, sacking, and other varieties of cloth from unmixed *Phormium* fibre, have been manufactured in Arbroath and sent out to the Colony; and, also, samples of a very superior kind of canvas made from an admixture of *Phormium* with Riga flax. The fibre used in these experimental manufactures was prepared by Mr. C. Thorne, by the use of alkaline solutions, and it is stated that such fibre would find a ready market in large quantities at from £60 to £90 per ton.* Whether this would be as profitable an application of the fibre as the production of hemp is, however, not yet established.

Colonial Museum,
Wellington, 1st August, 1872.

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* See Further Papers relative to *Phormium*, Par. Papers G. 17, 1872.

THE INFORMATION IN THIS WORK HAS BEEN SELECTED FROM THE FOLLOWING OFFICIAL REPORTS.

COMMISSIONERS appointed in 1869—
Thomas Macfarlane (chairman)
Arthur Penrose Seymour
Nathaniel Edwards
Charles Christie Graham
Thomas Kelly
Thomas Henry Potts
Arthur William Follet Halcombe
Frederick Wollaston Hutton
John Kebbell
James Kennedy
Samuel Locke
George Williams

REPORT—Parliamentary Paper, 1870, D. No. 14, 58 pages. Referred to throughout the work as "Commissioners, 1870."

COMMISSIONERS appointed in 1870—
James Hector (chairman)
Hon. Theodore Minet Haultain
John Kebbell

REPORT—Parliametary Paper, 1871, G. No. 4, 103 pages.

FURTHER PAPERS, 1871, G. No. 4A, 18 pages. Referred to throughout the work as "Commissioners, 1871."

ADDENDUM.

TABLE II. P. 47—The oiled *Phormium* rope mentioned in the Table as "still running," drew at the splice after 135 days, and did not break fairly. Its weight was 1lb 5ozs. 5 dwts., showing a slight gain instead of loss from this long continued wear.

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PLATE II. Section of leaf of *Phormium* showing microscopic structure to illustrate the description of Mr. Nottidge, page 63, Captain Hutton, page 66, and Professor M'Nab, page 92.

Microscopic appearance of fibrous bundles prepared by Native method, machinery, and alkaline solutions respectively, when broken under water.

PHORMIUM TENAX.

CHAPTER I.

Distribution of the plant.—Natural growth.—Causes of destruction.—Botanical species and varieties.

Phormium tenax, belonging to the Liliaceous family of plants, was first mentioned as occurring in New Zealand by Captain Cook, who says, "the country produced a grass plant, like flags, of the nature of hemp or flax, but inferior in quality to either; of this the natives make clothing, lines, nets, &c." "The leaves of the plant are perennial, hard, sword-shaped, from five to seven feet in length, with a flower stalk rising four or five feet above them, and bearing a profusion of flowers, followed by triangular seed-vessels, filled with flat and thin black shining seeds. It was introduced in the year 1798 into the south of Ireland, and has been found to flourish on the west coast of Scotland, though European winters are occasionally too severe for it."* This general description applies to the *Phormium* plant wherever it grows in New Zealand and Norfolk Island, to which countries its natural range is confined, but it presents many minor variations in habit of growth, according to the climate and soil. These differences are not, however, so great as might be expected to occur in a succulent plant that ranges through eighteen degrees of latitude, or from almost a tropical insular climate to a country possessing a severe winter climate, with prolonged frosts and snow-storms.

In the south, *Phormium* is never found far from the sea, nor at any great elevation, except on ranges near the coast. Thus, in the interior of Otago this useful plant is wholly wanting, or only represented by a few feeble bunches, irregularly scattered along the sides of the larger rivers.

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* Royle.

On the west coast of the South Island, which from the sea line to the limits of Alpine vegetation is essentially forest country, the *Phormium* plant is not of common occurrence, and is represented by forms having a very lax habit of growth. The only exceptions to this general rule are to be found in the neighbourhood of the larger rivers, where there are occasionally limited areas of ordinary flax swamp, as for instance on the alluvial flats at the mouth of the Buller and Karamea, and to the south of West Wanganui Inlet.

In the North Island the *Phormium* is also most abundant, and best grown near the coast, but is also found abundantly in the interior to an altitude of 2,000 feet.

It is, however, neither so abundant nor so universally distributed throughout the Islands as many have supposed.

What are frequently termed "flax swamps" have often merely a margin of *Phormium* plants round the edge, the greater part of the extent being covered by Raupo (*Typhus angustifolia*). It is true that in the swamps, when drained, a luxuriant growth of *Phormium* usually springs up, but this requires considerable time and large expenditure, so that such swamps cannot be considered as immediately available for affording a natural supply.

"The *Phormium* plant grows in bunches, or groups of plants or shoots: each shoot has five leaves. Ten of these shoots go to a bunch on the average, or, in all, fifty leaves. These vary, according to the soil, from five to ten feet in length, and each consists of a double-bladed leaf, which, when closed, is from two to four inches wide. The lower part of the outer leaves forms a complete sheath or flattened tube, and it is from this portion of the leaf that most of the gum exudes, and where the fibre is of least value.

"On rich 'flax land' there are over 2,000 bunches of *Phormium* to the acre, or 100,000 leaves. When sun-dried these leaves, after cutting off the gummy and useless lower parts, weigh about five to the pound, so that an acre of ground will yield nearly ten tons of dried leaves. Assuming the outer leaves only to be taken, the quantity will be reduced to four tons. Now, from experiment, it was found that 23·10 per cent. of apparently well-cleaned fibre could be obtained from the green leaf when all loss was avoided. Mr. Honeyman, of Dunedin, however, only produces about twelve per cent. of fibre, exclusive of tow. We may, therefore, safely anticipate a yield of fifteen per cent. upon these four tons, since they will have gained by their desiccation an additional four per cent. of fibre, calculated upon a loss of fifteen per cent. of water. This will give of clear fibre about twelve per cent. or three-fifths of a ton, only taking the outer leaves. Respecting the portion of tow to be added to the good fibre no certain data have been obtained, but in English flax the weight of the tow is about equal to that of the clean fibre, and, from the different character of *Phormium*, we may expect the proportion to be a good deal less.

"On hill land, owing to the shorter growth of the leaves, and the wider interval between the groups of plants, the yield will not average more than three tons to the acre."*

Many causes operate to destroy the *Phormium*. Cattle are very fond of it, and chew the leaf till the fibre is left hanging from the plant, cleaned of all vegetable tissue, and as bright as if prepared by hand. Fires are another fertile source of destruction; while in settled districts much has been cleared off to make way for more profitable crops.

"If cattle have access to a field that has been cut, they will destroy the plants altogether, by drawing out the young leaves to chew the butts, of which they are very fond.

"Attention is especially directed to a small caterpillar, which has made its appearance in several districts, and has very largely injured the leaves of the plants in the neighbourhood of Opunake, on the west coast of Wellington. It is to be feared that, if it continues to increase, its ravages will be seriously felt. It attacks the leaves in the early summer, and eats away the fibre in long patches, which leads to an extra quantity of tow being scutched out during the manufacture."†

"The *Phormium* plant is well known to be highly variable, but no attempt having yet been made to describe these varieties in a scientific manner, great confusion exists among the names. Much of this confusion appears to have arisen by supposing that those varieties which were considered nearly alike by the Maoris, and for which they sometimes used indifferently the same name, are really botanically allied, whereas the Maori system of classification was founded on one feature alone, namely, strength of fibre. All those varieties, the fibre of which was so strong as to enable them to draw it out in long ribbons, without breaking, they called *Tihore;* while those inferior kinds which had to be soaked and scraped with a shell in order to get length of staple, they called *Haro*, and it is evident that many varieties would thus be grouped together, which, under a different arrangement would be more widely separated. Thus the *Paretaniwha*, or yellow hill flax, is sometimes called a *Tihore*, although it is much more nearly allied to the common swamp flax, and is very different from the *Oue*, which is the commonest *Tihore*.

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* Hector and Skey, 1864.

† Commissioners, 1871.

"The colour of the leaf, and more especially of the midrib and margins, has been taken almost exclusively as the distinguishing mark of the different varieties; but this is altogether unreliable, for not only does the shade of colour of the margin differ in old and young leaves, but often different leaves of the same plant, and even different parts of the same leaf, have differently coloured margins. In distinguishing varieties, therefore, habit of growth, shape of leaf, size of flower stalk, and shape of the seed-pod, are to be considered as of more importance than mere colour of margin, or even colour of leaf.

"Dr. Hooker, in his *Handbook of the New Zealand Flora*, admits two distinct species of *Phormium* to exist in these Islands; although at the same time, he expresses an opinion that both are but races of one plant. The opinion of so distinguished a botanist must carry with it great weight, but it is quite possible that even he may have fallen into error through not having had sufficient opportunities of examining the plants in their living state, and by having had dried specimens sent to him with wrong names attached to them. Indeed, it seems almost certain that such has been the case, for he describes the pod of *P. colensoi* as similar to that of *P. tenax*, but smaller. It is of considerable importance that the existence of these two kinds of *Phormium* should be recognised; for, as will be seen, they produce fibre of very different strengths.

"*Phormium tenax*, Forst.—Seed-pod erect or inclined; 1½ to 3 inches long, straight or curved. Leaves very long. Flowers red.

"1. *Harakeke* (Common Swamp Flax).—Leaves coarse, loose, drooping, point generally blunt. Flower-stalk large—11 to 14 feet high, and 1 to 2 inches in diameter. Pod short, erect. Grows almost everywhere, but attains its largest size, (14 or 15 feet) on rich alluvial soil, by the banks of streams. Many sub-varieties are found, some with leaves dark blue-green above, and glaucous below, and some pale olive-green or bronzy. Some varieties have also the butts of the leaves coloured red for some distance up, while others are yellowish green almost to the very base. When the plant is stunted the flower-stalk is also small, and the best characteristic is the blunt point to the leaf.

"2. *Paretaniwha* (Yellow Hill Flax).—Leaves erect, slightly drooping at the tip, yellowish green, generally with red or orange margins, slightly glaucous below, point acute. Flower-stalk small, 4 to 8 feet high, and ½ to 1 inch in diameter. Pod short, erect. Fibre very good, soft and glossy. Plant seldom more than 5 or 6 feet in height; grows generally on clay hills. Passes into common swamp flax, but best distinguished by its nearly erect acute-pointed leaves. Probably often mistaken for *Tihore.*

"3. *Tihore.*—Leaves stiff, erect, narrow, never drooping at the tip, olive-green, glaucous below, points very acute or cuspidate, pink at the butt. Flower-stalk 9 to 10 feet high, and 1 inch in diameter. Pod erect, or inclined; seldom flowers, and still more rarely seeds. Plant seldom over 6 feet in height. Grows in rich, dry, alluvial land, never in swampy places. I have never seen it except where planted by the Maoris. I have here applied the name to that variety called *Tihore* by the Maoris throughout the Waikato, and which is probably identical with the *Oue* and *Tapoto.* It is best distinguished by its narrow, tapering, sharp-pointed leaves, and erect, close habit. It grows so thickly together that I obtained 186 sets for planting from two bushes.

"*Phormium colensoi,* Hook. f.—Seed-pod pendulous, 3 to 7 inches long, twisted. Leaves not so strong, sometimes quite brittle. Flowers red, yellow, or greenish.

"1. *Wharariki.*—Leaves erect or slightly drooping, generally rich green, not glaucous below, margins and midrib generally green, or yellowish white; butt white, never red, point acute. Flower-stalk 9 to 10 feet high, and 1 inch in diameter; flowers red. Plant seldom more than 7 feet high. The best and strongest variety of *P. colensoi.*

"2. There is also a yellow-leaved variety, which has sometimes yellow flowers, with which I am not so well acquainted. Its leaves are very brittle. It grows at Coromandel, between Kapanga and the Waiau.

"3. The same, or perhaps another variety grows on hills or precipitous places. Its leaves are of a yellow colour, and often so brittle that a man can break a strip more than an inch in breadth with ease."*

"In Waikato and the Bay of Plenty the *Oue* is the favourite variety;

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* Hutton.

on parts of the West Coast, the *Atiraukawa*; at Napier, the *Tapoto* (probably the same as the *Oue*, as Major Heaphy suggests); at Wanganui, the *Huhiroa*; and at other places the *Ngaro*, *Manunu*, and *Rataroa*.

"It has been ascertained that all large fields contain some plants of those kinds that are most esteemed by the Maoris, who were accustomed to transplant them to spots near their settlements. The list in Appendix I. gives fifty-five different names as applied to the *Phormium* plant by the Natives, but it is doubtful if more than twenty marked varieties can be distinguished.

"The European manufacturer cannot as a rule make any selection as the Natives do. He must take all that comes to hand, and, as the common sorts form a large proportion of most of the natural fields, the average of his fibre must, for the cause above-mentioned—apart from the inferior process of manufacture which he employs—be less valuable than that of the Natives.

"*Phormium* that grows on high or dry ground, though smaller, is in general finer and more easily stripped than that found in swamps—colonial rope-spinners preferring it, and being willing to give a higher price for it on this account.

"When two kinds are supplied in considerable quantities to any mill it would be worth the while of the manufacturer to dress and bale them separately."*

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* Commissioners, 1871.

CHAPTER II.

Mode of growth—Rate of growth—Root—Fans—Leaves—Flower-stalk.

"The growth of *Phormium* depends chiefly on the soil and position in which it is placed. In a large flax field of equable soil and moisture, where scarcely two bushes are exactly alike, and the finest varieties are to be found, there is great difference in the length of the leaves, while the same kinds that are stunted and yellow on dry and poor clayey ground, or in stagnant water, will flourish and rapidly increase if planted in a more congenial soil. The *Phormium* luxuriates in rich, moist, and well-drained ground, and reaches its greatest size on the banks of running streams, where the roots are abandantly supplied with nourishment by water that never stagnates about them. Wherever swampy ground has been drained (and not made too dry), there the flax increases in size, and becomes of a deeper green colour. This has been satisfactorily demonstrated by several manufacturers, and especially by Mr. Constable, at Waiuku, and Messrs. Nelson at Napier.

"The flax transplanted by the Natives does not appear to have improved in quality of fibre. The finest and whitest samples of Native-dressed flax, procured by the Commissioners of 1871, were prepared at Waikanae and Otaki from plants growing naturally in and around the swamps; and the Natives never plant an inferior flax by way of improving it.

"When every leaf has been cut quite down, as is generally the practice with those who supply the mills, the fan will send up within the first year from four to six full sized leaves. Captain Hutton says that 'swamp flax that had all the outer leaves taken off in January, had so many young leaves full grown by the end of April, that the casual observer would not have known that the plants had been cut at all.' Mr. Keleher, of Waiuku, says that flax cut eighteen months ago has now six full grown leaves, and that cut seven months since has three leaves besides the centre one. Mr. Ritchie, of Wanganui, states that the growth of flax between August, 1870, and January, 1871, has been 5 feet. Mr. Seymour, of Picton, says that he can cut leaves every twelve months, and that several from each fan had grown 3 or 4 feet long in five months. Messrs. Benn & Walker of Canterbury, find that flax can be cut every year, but they take care never to cut the centre leaves. Messrs. Stonyer & Co., of Kaiapoi, say that they can cut every twelve months; and that flax cut in December, 1870, and again in December, 1871, had in June following four and five leaves to each fan, from 4 to 5 feet in height. How long the roots will continue to bear this treatment cannot yet be determined, for it has not been observed that any plants have been killed by constant cutting; but it is reasonable to conclude that if cut down year after year the plants will gradually be weakened, and die out.

"At a few of the mills, where the supply of water is limited, more prudence has been exercised, and the two or three centre leaves of each fan have been left standing. Messrs. Nelson, of Napier, adopt this plan, and they find that in twelve months, after cutting all but the three middle leaves, four fresh ones have sprung up, and they have four outer ones so completely matured that, if left standing for three or four months longer, many of those on the outside will be so decayed as to be unfit for manufacture, and they have lost a considerable quantity of leaves in this way.

"Assuming that there is a similar growth in every flax plant, whether cut or not, *i.e.*, that four fresh leaves will start from the centre each year; and that there are on the average but eight or nine leaves on each fan, we arrive at the conclusion that after two years old the leaf, having reached maturity, commences to decay, and is not fit for manufacture.

"Whether well-established plants, annually cut, will send out as many new fans as a bush that is left entire, remains yet to be observed and noted; but probably they will not.

"The length and bulk of each leaf depends partly on the season of the year in which it makes its growth; for the flax grows all the year round, but more rapidly of course in the spring and summer. Mr. Rees found that after plants had been burnt down, the first leaves were shorter and less vigorous than those that grew after the plants had recovered the effects of the fire.

"The centre fan, that bears a flower-stalk produces no more leaves, but dies away the following year; it may therefore be cut quite down without disadvantage.

"The cultivated *Tihore*, flowers very sparsely, and often fails to perfect seed.

"The Natives suppose that the best time of the year for dressing is the winter and autumn, and that the fibre is more easily stripped out at those seasons; but none of the manufacturers have observed any difference, and it is doubtful whether any exists in the matured leaves. The Natives strip flax in the winter because they are engaged with their crops at other seasons."*

On this subject, Captain Hutton states that "The leaves of the different varieties of New Zealand flax vary from 3 feet to 14 feet in length, and from ½ inch to 5 inches in breadth, in the widest part of the leaf. They appear to grow all the year round, but more rapidly in spring and in summer than in autumn and winter. Swamp flax, that had all the outer leaves taken off in the end of January, had so many young leaves full grown by the end of April that the casual observer would not have known that the plants had been cut at all. The stumps of the leaves that are left on the plant still continue to grow also, but the younger leaves grow quicker than the older ones. Of four leaves cut down in the end of April, the outer one had grown 2 inches by the end of June, the next one to it, on the opposite side, had grown 3 inches, the next 6 inches, and the inside leaf 17½ inches. Of those sets of the plant that do not flower, the leaves last probably three or four years and then decay, new ones taking their place; but when a set produces a flower-stalk, the set itself, and all the leaves upon it, die down the following spring."†

"Seventeen of the best marked varieties of the *Phormium tenax* were exhibited in Wellington by the Commissioners of 1871, and tended to show that the difference of character which the species is capable of assuming, is to be found chiefly in the colour, especially of the edges and midrib. The seedlings of the same varieties, raised in December, 1870, prove that the rate of growth of the plant in its earlier stages is exceedingly slow, and, as far as can yet be observed, it appears that they do not inherit the peculiar characters of the varieties from which the seed was obtained. This indicates that the only method of perpetuating varieties must be by subdivision of the root. The structure and mode of growth of this root, or rhizome, are explained by the sectional specimens and diagrams (Pl. II.), which show that each fan forms a true underground stem with fibrous rootlets, which stem, after a growth of several years, with a succession of leaves, bears a flower-stalk, and then decays; but also during the period of its growth gives off lateral buds, from which new fans proceed, acquire their own roots, and finally become independent plants, clustering together and forming large bushes such as are usually seen. In the propagation of the plant, therefore, these lateral fans, as soon as rootlets have been formed, may be removed and transplanted in the same way as tubers, and will be vigorous in proportion to the amount of nutritious matter which has been accumulated in them. Further observation is yet required to determine how far the development of the flower-stalk, the increase of the root, and the formation of new fans is affected by the repeated cutting of the leaves for manufacture."*

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* Commissioners, 1871.

† Hutton, 1871.

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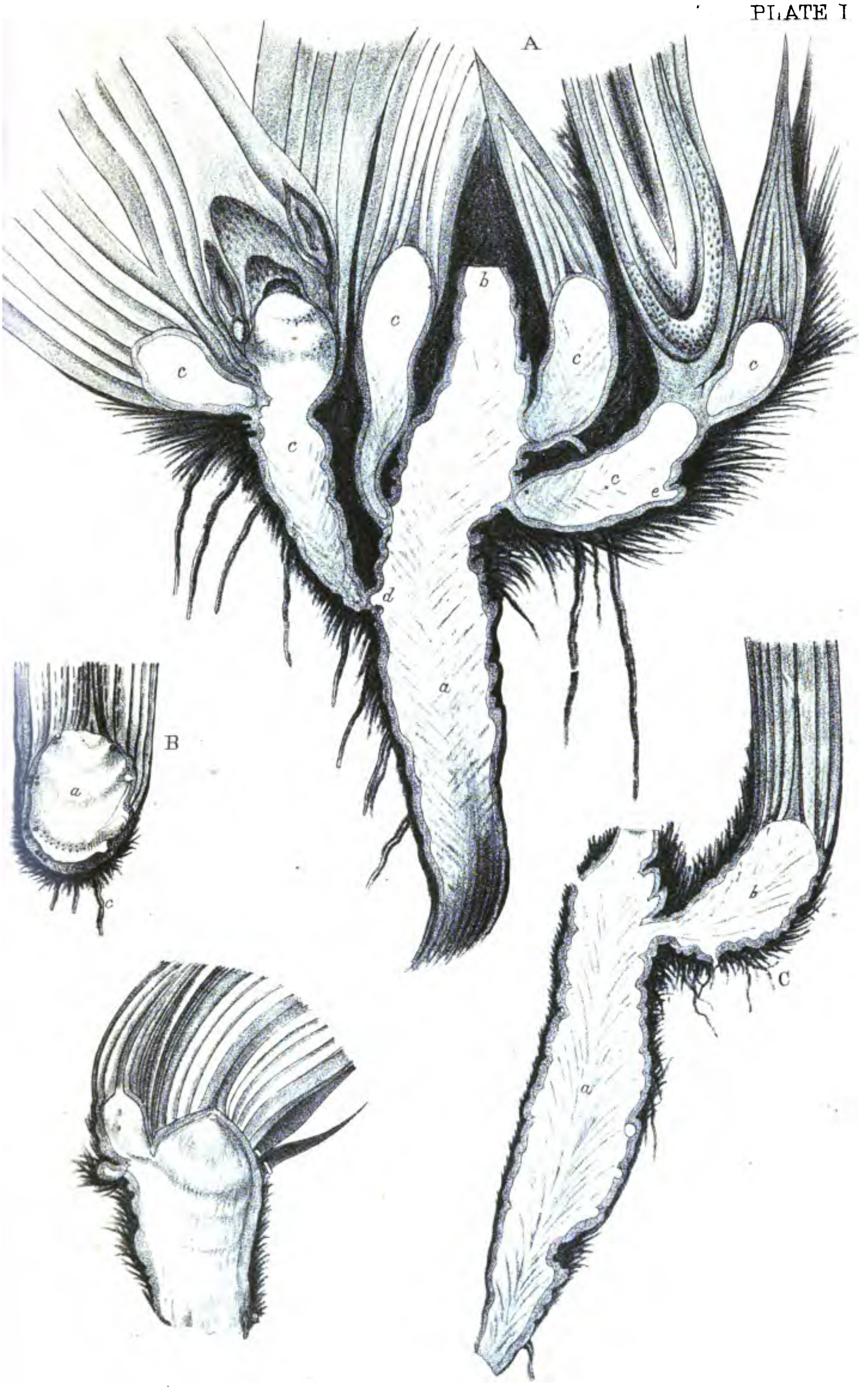
* Commissioners, 1871.



STRUCTURE OF ROOT OF PHORMIUM TENAX.

del. et lith.

CHAPTER III.

Cultivation.——Transplanting.—Propagation by suckers.—Experiments in Botanic Gardens, &c.

" PHORMIUM will grow in almost any soil, but the more suitable the soil the finer the quality. It grows best on light rich soil, by the sides of rivers and brooks, where sheltered from the wind.

" A rich, dry, but not deep, clay soil, having yellow clay subsoil, with plenty of light and air, is very suitable, but the greatest crops are reared on high volcanic soil.

" A well-drained swamp gives large returns; this fact having been verified by observation in the Upper Waikato and elsewhere.

" Stagnant marshes are prejudicial to the growth of flax, but as soon as they are drained and the water sweetened, the same flax will grow rapidly. The drains should be open, and the water therein should flow about twelve inches below the surface. If practicable, swamp land should be ploughed as soon as it is dry enough for the purpose, and allowed to remain all summer, or till March, when it should be again ploughed, and planted immediately thereafter. The soil will be well pulverized by that time. Should the land become very dry in summer, the drains might be stopped, so as to irrigate the soil; for any land that is periodically inundated is very suitable for promoting rapid growth. Alluvial soil should also be ploughed in winter or spring, and allowed to dry till autumn, when it should again be ploughed and planted, that is, in March or April, or as soon as the autumn rains arrive—in fact, the earlier the better, for the plants make roots all winter, and are ready to come away with a vigorous growth in spring.

" The plants should be sown in rows, and in the same way as trees are planted; but opinion differs as to the distance from row to row, and from each plant in a row. It seems to be overlooked that planted *Phormium* will not be allowed to grow into large bushes, as it does in the uncultivated state. On the contrary, the constant cutting which will be carried on will confine it within a comparatively limited space. The roots thrown out by the first plants will undoubtedly spread around it, but still it will always be practicable to keep the bunches within a small space. With this view the rows might only be four feet apart, and only three feet between each plant in a row. At all events, the quantity of soil that would be saved in this way would justify the experiment on a small scale. In this case, the roots should be planted across the lines in rows. Six feet is generally recommended to be between each row and each plant, because closer planting might impoverish the soil; but it should be kept in view that flax needs shelter, and the proximity of the plants to each other would afford this, and assist in drawing up the leaves and making finer fibre. If suitable land is chosen, it is thought that impoverishment of soil will not result from the close planting.

"With the view of still further economizing space, it has been suggested that about ten or twelve rows should be planted, then a break of 10 or 12 feet should be left for drays to pass along and collect the leaves when cut. Then other ten or twelve rows should be planted, then another break, and so on. The size of the ground to be planted must however regulate this.

"About 1,000 roots planted six feet apart each way will cover an acre of land, but if the land is planted 4 feet by 3 feet, as recommended above, about one-third more will be required for an acre.

"In one bush of *Phormium* there will be from 20 to 50 roots for transplanting.

"Opinions differ also as to the number of roots that should be planted together; one, two, and three, are variously recommended. If two or three are planted together, a larger space of ground would require to be left around. Care should be taken to avoid planting the roots from which a seed stem has been thrown out, or planting the centre portion of an old plant, which is not so productive as young shoots, and has a tendency to run to flower, when it requires more nourishment than all the leaves do. The flower-stalk should therefore be cut down as early as possible, and when this is done the cut part should be rubbed over with a little earth to prevent 'bleeding,' or better still, twisted off.

"But if the close planting be adopted, only one root should be planted at one place.

"The maturity of the leaf is ascertained by its texture and firmness, or by its being split at the point, or by the recurving of the blades from the central midribs. The leaf of the best *Phormium* should be over five feet in length excluding the butt. The top of the leaf, says Mr. Locke, should feel soft to the touch, and droop a little; this occurs in winter.

"The Natives say that the *Phormium* should not be cut from the time the flowering-stalk shoots until it dies again, as the fibre is then very brittle, and of a red tinge; and during winter they carefully preserve their flax swamps. But if a permanent supply is to be kept up, it will be difficult, if not impossible, to comply with their notions; and hence it has been suggested, as one mode of remedying this, that the flower-stalk should be cut, but the best time for cutting it requires experience; it is thought, the sooner the better.

"The general understanding is, that in cutting *Phormium* only the outer leaves should be cut, and that in doing so great care should be taken not to injure the leaves which enclose the centre shoot. With this view the knife should be inserted at the leaf enclosing the centre shoot, and the outside leaves, two or three on each side, cut downwards and slanting outwards; but no leaf should be cut before maturity, as this also weakens the plant and makes it liable to go to flower."*

"The Maoris never cultivated the *Phormium* with the view of improving the quality or quantity of its fibre. It was only those who lived in the bush, or at inland settlements, where it did not abound, who took the trouble to make plantations near their villages. Those within easy reach of any large *Phormium* field were able to procure what they required from the choicer varieties that are always to be found growing in those places. At the present time it is rarely transplanted by them, as they no longer depend on this material for their ordinary clothing, and require but very little of the better qualities for their fine mats and other ornamental purposes.

"The majority of Europeans who are concerned in the *Phormium* industry have paid little or no attention to its cultivation. The extensive fields, in their natural state, have hitherto been amply sufficient to supply all that they have required; and the low prices in the English markets have so limited the production that there has been no prospect of a scarcity of the raw material; and the manufacturers are unwilling to invest more capital than is barely necessary for machinery, plant, and working expenses. But there are a few who have thought it worth while to expend time and money either in planting considerable tracts of land, to prepare for a future greater demand, or in making experiments on a small scale to observe and note the growth, and to test the possibility of improving the plant; or of raising a supply by cultivation with profit and advantage."†

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* Commissioners, 1870. † Commissioners, 1871.

Writing in August, 1871, Mr. H. C. Field, of Wanganui, says :—"Two years ago, in consequence of seeing in our local papers some statements, copied I believe from Auckland prints, as to the rapid growth of *Phormium*, which from my own experience I thought were exagge rated, I planted out a number of fans of a good variety on different soils to test the result. The present condition of the plants is as follows:—

"No. 1. Twenty fans planted in pumice sand: One has now five fans, three have four, four have three, seven have two, four have still only one. The whole grew; but one which had increased to three fans, had its roots exposed by the wind during the early part of last summer, and was uprooted and destroyed by the salt gale in February.

"No. 2. Ten fans planted on strong clayey alluvium, which, however, had been some years under cultivation: Two have now two fans each, four have one, and four never grew.

"No. 3. Twenty fans planted on a piece of boggy ground undrained: Two have now two fans each, seven have one, nine were killed by some sharp night frosts in the spring after they were planted, and two were buried under a slip of the neighbouring bank.

"I also planted twenty fans on a piece of drained swamp, and they all grew and were doing well, but some cattle, which broke in in the summer during my absence from home, dragged the whole of them out of the ground.

"At the same time as I planted the above, a neighbour who was embarking in the *Phormium* trade, planted 30 acres partly on shallow-drained swampy soil, resting on white clay, and partly on a slight rise (old manuka ground) where the soil consisted of vegetable mould resting on yellow sandy clay. The whole area planted had been some years in cultivation, and in order to ensure the proper preparation of the ground, the superintendence of the work was entrusted to a professional nurseryman. The fans were planted four feet asunder, in rows alternately four feet and ten feet apart. A very large proportion of the sets (in one paddock I should say nearly half) failed to grow, and those which are still living have certainly not more on the average than three fans to each plant; indeed I think it doubtful if the few which have more may not have been double fans when planted. In both the above cases no pains have been taken to keep the ground around the plants stirred or weeded; my own object having been to see how the plants would thrive with no more attention than similar ones put out by settlers would ordinarily receive, and my neighbour having been disappointed, and given up the business. In both cases the plants would not at the present time yield more than two or three leaves each without weakening them, and I observe that those which have not increased the number of their fans would yield the largest leaves, and nearly or quite as many as the others. There seems in fact an equal amount of vigour in the plants, though its development has taken a different direction. My own plants on the pumice soil are considerably smaller than the others, but I think this arises partly from their being close to the house, and consequently having often had leaves cut from them by my children.

"I do not know whether saline particles in the air are beneficial to the growth of *Phormium*, but it appears likely that this is the case, because while all the coast country along the north shore of Cook Strait, from the Tararua to Mount Egmont, contains abundance of good *Phormium* for manufacturing purposes, directly one gets among the hills a few miles inland, the only plants which will yield any appreciable amount of fibre are those growing in native cultivations. During the last two years I have traversed a very large extent of the country inland of this district, and have found everywhere only the most utter rubbish in the shape of wild *Phormium*. Even in the old native cultivations, bushes which are doubtless descendants of good ones planted by the Natives, have degenerated so as to contain no fibre worth extracting. The leaves are very thin, and the fibre so fine, and so firmly attached to the woody matter, that I believe the machinery generally employed at present would break it all to pieces. The soil of the region in question is everywhere extremely rich, and so deeply and universally rooted by the wild pigs that the difference cannot arise from any want of cultivation. The overgrowth of koromiko scrub may have something to do with it, but as splendid *Phormium* is constantly found similarly overgrown in the old cultivations near the coast, it would seem that this alone cannot account for the change. The absence of wind among the hills again can scarcely be the reason, as just as constant a calm prevails in sheltered cultivations near the coast. From whatever cause it has originated, there can be little doubt that the degeneracy, in the case of the bushes in the old cultivations, has been accomplished in the forty or fifty years which have elapsed since that part of the island was abandoned by the Natives as a place of residence, and in some cases apparently in a far shorter period, if not actually in so short a space as fifteen years, which seems to have been about the time since one very extensive patch of cultivations was given up. I mention the matter because its cause may be worth investigating, though the Natives whom I have questioned on the subject, seem unable to throw any light upon it."

Mr. Finnimore planted some thirty acres, near Wanganui, at a considerable expense; and Mr. Hirst, writing in March, 1871, states that the Patea Flax Company expended £467 in cultivating 75,000 plants of the best varieties, on twenty-five acres of land; but in both instances the outlay was so great and the prospect of pecuniary success so small, that the plantations have subsequently been neglected, and it is doubtful whether they will be maintained.

The following account of the plantation is given by Mr. Hirst:—

"The flax is planted in rows six feet apart, with a space for carting of ten feet at every fourth row. Three plants are placed in each hole, well rammed, and the holes are six feet apart.

"The contract for digging the holes and planting—the ground having been previously cleared but not ploughed—was 9s. 6d. per hundred holes.

"The plants cost 6s. per hundred plants for procuring, and were gathered under the direction of an experienced gardener, who has devoted some time to attaining a knowledge of his business.

"The cost for cartage varied from 5s. per hundred plants to 1s. 6d. per hundred, according to distance, costing for the 75,000 plants, £123.

"In selecting the plants, all plants which would throw out seed stems, were rejected, or will have to be replaced at the contractor's expense.

"The sorts planted consist of the following:—

" *Oue.*	Red edge.
" *Atiraukawa.*	Light bronze edge.
" *Huhiroa.*	Black narrow edge.
" *Korako.*	Black edge, light colour in back of leaf.
" *Atewheke.*	Scarlet edge.
" *Tihore.*	Orange edge and keel.

"The planting of the twenty-five acres, including the digging the holes, procuring and planting and cartage, but exclusive of clearing and fencing, amounts to about £467, or £18 13s. 6d. per acre."

"Mr. Constable of Waiuku, near Auckland, in September, 1868, planted about half-an-acre of land, of fair quality (though rather dry for *Phormium*), which he had carefully prepared and manured, with three varieties of *Tihore*; and in May, 1871, these were healthy and vigorous, and, in some cases, had thrown out twelve and thirteen, and in one instance, twenty-two fresh fans; but the majority would not average more than five or six. When two years old a few leaves were dressed by the ordinary mill process, but the fibre was not superior to that obtained from common swamp *Phormium,* as it was harsh and brown. The breaking strains were—*Rataroa,* 86; *Oka-Oka,* 77; *Ngarowaka,* 61.

"There is a plantation of the same age in the Domain Gardens at Christchurch, the plants having been procured from the North Island; but these have not been so prolific, owing either to colder climate or to the growth of the sets having been retarded, by having been carelessly removed and kept a long time out of the ground during transit. One variety (name not known) has been quite cut down by the frosts, showing that it is too tender for that part of the Colony.

"Mr. Hulke, of New Plymouth, has formed a nursery of 2,000 plants, of the best varieties, in three-quarters of an acre of ground, which he offered to make over to the Government on condition of being reimbursed for his outlay, and he undertook to superintend its management if a sum not exceeding £20 a year was provided for working expenses. This offer was accepted, and the garden is now held under a lease by the Government for ten years. There are also a quantity of seedlings, which have grown very well, but cannot be depended on as useful varieties, and they will take a much longer time in coming to maturity than those plants that have been raised by off-sets from approved and established bushes. Other persons have also sown seeds, with no more favourable result. In many private gardens a few plants have been introduced, and carefully attended to. In Dr. Hector's and Mr. Mantell's gardens at Wellington, sets of variegated *Phormium* that were planted two years ago have now from three to six fresh fans, and one of *Manunu* that has been in the ground seven or eight years has forty-four. Some plants of the same variety, which were planted more than twenty years ago in the garden now belonging to Mr. Quick have increased one hundred fold.

"Messrs. Nelson, at Napier, have also planted flax, and sets that had been in the ground seven months had sent up four and five leaves, and occasionally two or three fresh fans. But in all these cases of recently planted sets, they have not reached the length of leaf and vigour of the old bushes, though the leaves become larger as the roots increase, and are better established. This proves that increase is not sufficiently rapid, nor vigorous and luxuriant enough to justify a hope that cultivated *Phormium* will yield a fair crop of leaves within four years, which opinion coincides with that expressed by many of the Natives themselves.

"A portion of the Botanic Gardens at Wellington has been set apart for the cultivation of *Phormium.* Seeds from seven varieties, from Taranaki, were sown on the 4th November, 1870, and were above ground on the 24th of the same month. In April, 1871, they were planted out, being then five inches high. On the 1st August, *Manunu* had four or five leaves of an average height of nine inches. *Parekoritawa* (variegated) had as many leaves, which were stronger, being one foot in length and half-an-inch broad, but there were no signs of variegation. *Huhiroa,* same number of leaves, but weaker and membranous, and not more than four inches long. *Takaiapu* and *Raumoa,* leaves five or six inches larger, and a-quarter of an inch broad. *Atiraukawa* and *Korako,* same as *Huhiroa.*

"Three hundred sets, of fourteen varieties, from Mr. Hulke's nursery, at New Plymouth, were planted in April, 1871, after having been out of the ground for nearly three months, and they are now (August, 1871) beginning to sprout; but one hundred sets from Wanganui, planted a little later, in very wet ground had not, in August, 1871, made a start.

"At St. John's College, near Auckland, there is a quantity of *Rataroa,* one of the strongest varieties of *Tihore,* procured by Bishop Selwyn, from the East Cape, some twenty-five years ago. It was planted in a gully, which had been drained; the upper part was quite dry, but a small stream of water flowed from springs lower down. All the sets have multiplied greatly, and now form large bushes, with as many as one hundred fans; but there are rarely more than six perfect leaves on each fan, the seventh and eighth being quite unfit for manufacture. The leaves of those sets that were planted in the moister ground are very much longer and stouter than the others, reaching a length of eight and nine feet, whilst those in the driest parts, and by the side of the hill, are barely three feet high. There does not appear to be any difference in the quality of the fibre, and both large and small leaves are stripped with equal facility by the Maoris. The more luxuriant leaves have a deeper and richer green colour, but in shape and colour of the edge and keel they remain alike."*

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* Commissioners, 1871.

CHAPTER IV.

Strength of fibre from leaves of different ages.—Quantity of fibre in leaves of different ages.—Method of determining the strength.

"The plantation at St. John's College, mentioned in the preceding chapter, afforded a good opportunity for making experiments as to the strength and quantity of fibre in leaves of different ages, and a Native was employed to dress some; the leaves were cut for him, and kept in separate bundles, so that they should not be mixed.

"After stripping and cleaning, some of the hanks were boiled in soap and water for an hour, without improving the appearance and texture in any way; some were washed and rinsed in warm soap and water for a few minutes, and this both softened the fibre and improved the colour; others were soaked in cold water (repeatedly changed) for different periods, from twelve hours to five days; but the longer they were kept in soak, the worse the colour became.

"A few of the centre immature leaves were stripped, and the fibre was very white, soft, and silky, equal to any of the best samples of native-dressed, which have probably been prepared from young leaves of this kind, and could not, therefore, be obtained in any quantity, even if the Natives were disposed to supply it. On being tested for strength, twisted tightly into a double strand in the usual manner, it was found that the fibre of these half-grown plants bore a greater average strain than any of the others, as follows:—

Centre leaf;	breaking strain	... ...	81
1st pair leaves,	„	... ...	70
2nd „	„	... ...	72
3rd „	„	... ...	78

"As it was impossible that these immature fibres could be as strong as those that were fully grown, it was conjectured that their softness had enabled them to bear a great torsion, and the strands were then tried without being twisted at all; and though the young fibre proved, as was expected, to be the weakest, yet the whole of the strands bore a considerably greater strain than when in their twisted state, so that it was found necessary to reduce the fibre to one-half, as the spring balance then in use, which weighed up to 300lbs. only, was not strong enough to break the full quantity of twenty grains to one foot. The result was, that an untwisted, single strand, of ten grains to a foot, broke as follows, the results, as in former cases, being reduced to a standard of Manilla, equal to 100:—

Fibre of centre immature leaf; breaking strain			104
1st pair of leaves,	„	...	122
2nd „	„	...	116
3rd „	„	...	113

"Since then, a different adjustment has been made with the machine, and double strands of native-dressed *Rataroa*, slightly twisted, have borne the following strain before breaking:—

1st pair of leaves; breaking strain		...	104
2nd „	„	...	104
3rd „	„	...	110

"These are averages of many trials. The maximum strain was 129, showing that some of the *Phormium* is far stronger than Manilla, or any other fibre of the hemp class.

"Another trial was made with fibre of the same variety, stripped by White's machine, with the following result:—

1st pair of leaves; breaking strain		...	87
2nd „	„	...	79
3rd „	„	...	81

"To ascertain the relative quantity of fibre in different aged leaves, seven leaves of each growth were taken from the same plants, weighed, and passed through White's stripping machine:—

			Per cent.
1st pair leaves,	weighing 16 oz.,	gave 4 oz. of fibre...	25
2nd „	„ 20 oz.,	gave 4½ oz. „ ...	22·5
3rd „	„ 12 oz.,	gave 2¼ oz. „ ...	18·7

"As these fibres were not thoroughly cleaned, and a great deal of vegetable tissue still adhered to them, this experiment only showed that the relative quantity was greatest in the youngest leaves; and a more exact trial was made in the laboratory with leaves of the *Mununu*, which gave from the half of the

			Per cent.
1st leaf,	weighing 50·1 grammes,	7·77 grs. of fibre...	15·51
2nd „	„ 60·0 „	10·50 „ ...	17·18
3rd „	„ 54·3 „	8·30 „ ...	15·28

"The advantage of quantity was in favour of the second leaf this time, and another trial gave from—

	Per cent.
1st leaf, weighing 58·55 grammes	16·26
2nd „ „ 52·68	17·89
3rd „ „ 36·35	19·06

"Here the third leaf had the largest relative quantity of fibre, but was little more than three-fifths the weight of the first leaf.

"Although these various experiments do not give invariable results as to the relative strength and quantity of fibre from leaves of different ages, yet it may be concluded from them that they are nearly equal in both respects, and may be used indiscriminately in manufacture."*

Captain Hutton gives the result of experiments applied to test the strength of the fibre as it occurs naturally imbedded in the leaf, as follows:—

"In order to ascertain the relative strength of the different varieties I took strips of one-eighth of an inch in breadth from the middle parts of young but full-grown leaves and broke them, by means of a spring-balance, which I had previously tested, and the following are the average results of many trials made on the leaves of four different plants of each variety:—

Tihore	broke with a strain of	48 lbs.
Harakeke	„ „	42 lbs.
Paretaniwha	„ „	42 lbs.
Wharariki	„ „	34 lbs.

"That *Tihore* is stronger than swamp flax, is contrary to the opinion of many. Major Heaphy (Trans. N.Z. Inst., Vol. II. p. 116) expresses the opinion that the fibre of the *Oue* (*Tihore*) is of 'so brittle a character as to require a mode of preparation in which a knife or scraping instrument may not be used;' but I conceive that the real reason for the difference in the preparation was that the fibre of the *Tihore* is so strong that the Maoris were enabled to pull it away from the tissue so completely, that scraping with a knife or shell was unnecessary. I also made some experiments on the strength of prepared fibre of the different varieties, but found that the small scale on which I was obliged to experiment gave results so discordant that they were of no value. This was probably owing to the difficulty of dividing the strain equally among the different fibres; and useful results can only be obtained by twisting the different varieties up into rope, and then breaking them.

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* Commissioners, 1871.

"It appears to me, therefore, that *Tihore* is the most valuable variety for all purposes; but the kinds that should be cultivated would depend upon the nature of the soil; for swamp flax of excellent quality could be grown in places where the superior *Tihore* could hardly live. But all the varieties of *P. colensoi* should be carefully avoided, or, if manufactured into fibre, should not be sent into the market under the same name as fibre from *P. tenax*, or the latter will fall in the estimation of the public, from the inferior strength of the former."

"For comparison with this experiment it may be useful to state that the breaking strains of a large portion of the collection of prepared fibre exhibited in 1871 were determined, and showed that the strength of the several descriptions reported at that time varied from 53 to 84, with an average of 69, as compared with Manilla, which was taken as the standard at 100. On the other hand the samples of native-dressed fibre ranged from 70 to 122, with an average of 91.

"It should be stated that in all experiments undertaken to test the strength of the different samples of fibre, the breaking strain was determined by an apparatus which applies a gradually increasing strain to the strand that is being tested; one end being attached to a spring balance, and the other to a frame that is carried steadily down by a screw. The indication of the balance shows the strain on the fibre at the breaking point, while the extension of the cord can be observed. The ends of the cord are carried over a smooth metal bar, and attached to an iron peg in the same manner as the strings of a violin. The quantity of each sample to be tested was carefully obtained by the weight of two portions of well cleaned fibre, cut to a constant length; these weighed quantities were then carefully 'laid' in a machine planned by Mr. Kebbell, which insured exact uniformity of twist in each cord. The breaks were all reduced to a standard of Manilla, to obtain which a series of thirty strands of that fibre, of the uniform weight, viz., twenty grains to one foot, were broken, and gave an average breaking strain of 347lbs. From this the strength of all the other fibres was centesimally calculated.

"One of the chief uses of the comparison which was thus instituted was the observation of the degree of uniformity which is obtained in the quality of fibre placed in the market by the various shippers; this uniformity being most evident among the samples procured from the Northern and Central Districts.* Those from the South showed a greater difference of quality, testifying that some of the manufacturers in that district did not perceive the necessity of scrupulous care in every process of preparation, were behindhand in availing themselves of the improvements that experience had suggested, or were adopting methods that did not produce the most desirable results. Nevertheless, it was observable that there had been a general approach towards that uniformity of quality, without which the fibre can never attain to a permanent position in the English or Foreign markets; and there is now a marked absence of those inferior qualities which were formerly sent home in such abundance, and which, more than anything else, conduced to create the unfavourable impression so prevalent in the home markets with regard to the *Phormium* fibre."*

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* For convenience of reference the Colony was divided into districts—the Northern comprising Auckland, Hawke Bay, and Taranaki; the Central, Wellington, Nelson, Marlborough, and Westland; the Southern, Canterbury and Otago.

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* Commissioners, 1871.

CHAPTER V.

Native method of preparing the fibre.

So many contradictory accounts having been given of the method employed by the Maoris in the preparation of *Phormium*, it was thought desirable to obtain accurate information on that subject. This duty was undertaken by Colonel Haultain, who, during the summer of 1870-1, visited the native villages on the West Coast of Wellington province; and the results of his researches in that district, and also information gathered during a visit to Auckland and Hawke Bay in the winter of 1871, will be found in the following notes:—

"6th December, 1870.

"There are but two varieties of *Phormium* growing on the flat land about Otaki, Manawatu, &c., called by the Natives *Harakeke* and *Wharariki*. The latter is apparently a variety of *Phormium colensoi*, found on the sand hills near the beach, growing from six to eight feet high, with a palish green leaf and edges of the same colour, and small flowers with yellowish-green sepals, but as it was not in fruit I could not determine whether the capsules were 'twisted' or 'drooping.' It is not common (I had to walk more than a mile before my guide could show me a plant), and it is rarely cut by the Natives, who say that the fibre is weak and useless. An examination with the microscope proved that the quantity of fibre was very small in comparison with other varieties. The *Harakeke* is abundant, and the leaves are often twelve and thirteen feet long. It grows luxuriantly on any dry ground round the edges of swamps, or when away from stagnant moisture. It is subdivided by the Natives into *Tuhora* and *Tukura*, according to the length of the leaf, the former being the longer; but I could not perceive any difference between the fibres either in strength or in colour. It cannot be stripped without the aid of a shell, in which it differs from the *Tihore*.

"There are no native plantations of *Phormium* in this district; the choice leaves of the *Harakeke* are fine and white enough even for their best mats; and any *Tihore* that is wanted for special purposes is brought from the upper part of the Wanganui River, where it grows in old gardens, or from Kawhia.

"In preparing *Phormium* for the finer purposes, the Natives select clean unspotted leaves of a year's or eighteen months' growth, and use the upper portion only, cutting off the leaf about six inches below the point where the two blades adhere together, and rejecting the coloured edges and keel also. They strip the fibre from the upper surface only (that surface which is inside when the two blades are together), cutting the under side across, and then, with the round edge of a mussel-shell, tear up the whole row of upper fibres, bringing away the cuticle also, which has to be removed afterwards.

"I asked the woman, Annie Kanàra, who was working for me, to strip the other side of some of the leaves; she laughed at such an idea, but tried, and after failing several times succeeded with about a dozen leaves, and then objected to waste time on any more. This under fibre is not as abundant as the other, but extends the whole length of the leaf from the butt to the point; it is equally fine and strong, and there was apparently no difference in the ultimate fibres when microscopically examined, but it is too green in colour to mix with the other, as it is difficult to separate it from the cuticle and surrounding cellular tissue. The breaking strain of the only strands I could prepare was 198 ℔s. *

"After stripping the fibre of the upper (or right) side, it was well scraped with the edge of the shell to remove as much of the cuticle as possible; and when a small hank of a dozen or twenty leaves had been finished, it was thrown into a tub of water to be kept moist until a sufficient quantity was ready to be taken down to a running stream, where it was washed and scraped with the shell over and over again, till all the cuticle, gum, &c., had been removed, when it was hung up to dry, and afterwards worked and twisted with the hand. It took Annie Kanara the greater part of two days to gather leaves and prepare four or five pounds weight, and she would not part with it for less than 1s. per pound.

"It was very white and soft and bright, for the leaves had been carefully selected, and the breaking strain was from 210 ℔s. to 275 ℔s. But what an amount of hand-labour is necessary to produce a ton of this fine quality, and what a waste of fibre! At least one-half the leaf is discarded, and the fibre from one side of the other half is rejected, so that the Maori obtains from each leaf only one-fourth the quantity that would be secured in machine-dressing; and as he would not select more than one in four of the leaves of any full-grown bush, the

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* **The breaking strain here given was obtained in the manner described on page 22.**

European mill-owner, who cuts down the whole plant, could in the first year produce sixteen tons of his fibre from the same ground that would give only one ton of fine native-dressed *Phormium.*

"In preparing *Phormium* for their mats, the Natives take much more time and trouble than has just been described; they soak the fibre in running water for four days, and then beat it with a stone or mallet; and this process is repeated over and over again for four or five weeks, or even for much longer periods, but I have no doubt that this excessive manipulation weakens the fibre, though it makes it very soft and durable.

"I dare say that a few tons of the ordinary washed fibre could be procured from the Natives for less than 1s. per ℔., but not at Otaki. It was attempted to procure one ton through Mr. Bevan, an old settler and rope-spinner at that place, but he said he could not get it for less than 1s. per ℔.; and the Rev. Mr. M'William, who kindly assisted me in securing the services of Annie Kanara, said that he had at first applied to the native woman who had lately prepared some for Bishop Hadfield, which was sent to England by Mr. Sewell, but she refused to work at any more, as she considered she had been insufficiently paid for what she had done. I believe she got 4d. per ℔. for it. Annie Kanara got 5s. from me for her two days' work, and would have earned as much if she had been stripping flax for the rope-spinners. These pay 1½d. per ℔. (£14 a ton) for fibre that has been merely stripped and tied up into bundles. Of course the Natives take all leaves as they come for this purpose, but they only use the upper portion as they cannot strip the butts, and the spinners object to longer lengths than 3½ or 4 feet, as being unmanageable. I got a sample from Mr. Dodds at Otaki, which he had prepared for rope-making by hand-hackling it, the labour and loss of weight bringing the cost up to £25 a ton (the breaking strain was 188 ℔s). He had sent five or six tons to England, and it sold there at £25 a ton, leaving him to bear the cost of transport to Wellington, £6 a ton, and thence to England £8 or £9 a ton more.

"Mr. Bevan is not making rope at present, as the Natives are demanding 2d. instead of 1½d. a ℔. for the *Phormium.*

"Waikanae, 3rd January, 1871.—A number of women, and some of the old men, are very busy preparing the half-ton that was ordered by the Commissioners. They do not consider that £20 is by any means a sufficient price for it, and they are under the impression that they are to receive 5s. a day, besides the price of the *Phormium,* from the

Government. They tell me that they quite understood the terms proposed, viz., that they were to get £20 down, and also any balance on the home valuation after expenses had been paid; but that the women would not work on those terms; and Wi Tako and others asserted that Mr. Halse, Mr. Young, and Mr. M'Lean had promised them each 5s. a day, in addition to the amount to be paid by the Commissioners. I told them that I was sure this was a mistake on their part. I am, however, not surprised at their objecting to £40 a ton as not sufficient, for I do not believe they could earn an average of 1s. 6d. a day each at this rate for fine thoroughly cleaned *Phormium*, such as was stipulated for. It takes so much time to free it from all the scull, and the suitable leaves are not readily procured; they can get but little of it in the immediate neighbourhood of their settlement, and a party of them have gone off to-day some three or four miles to a better locality, taking their food and blankets with them, and are not to return till to-morrow. It is difficult to get any accurate estimate of what quantity a native woman can prepare in a day. At a large meeting I asked the question, and Mary, Wi Tako's wife, said that some could do 1lb., some 2lbs., and others as much as 4lbs., according as they were fortunate or otherwise in quickly finding the proper leaves. Wi Tako said that he thought that a woman could do as much as 10lbs. in a day. Some others assented to this provided she had not to collect the leaves herself, and that it would take a woman two days to collect leaves enough for 10lbs. of the fibre, but it is evident that they have no clear idea as to weight in pounds. I examined the day's work of several women, and they certainly did not average 5lbs. Wiremu Tamihana (the teacher) showed me what his wife, Penelope, one of their best workers, had got ready; it filled two 100lb. flour-bags, but there certainly was not one cwt. of fibre and he said that she had been working steadily at it since the 10th of November, and had not missed a day, except Sundays, so that she had not averaged more than 2lbs. a day, but she was fully calculating on getting 5s. a day all this time, in addition to her share of the £20.

"The women here do not prepare the *Phormium* in exactly the same way as that I procured from Otaki. This is stripped and then allowed to dry before the scull is scraped off, and it is not touched with water. It has, in consequence, a harsher feel than the other, and is not so silky in appearance. I pointed this out to Mrs. Tako, and she admitted that the washing was an advantage, and showed me a few hanks that she had treated in this way. It would add to the labour considerably if they took their fibre down to the river here to wash it, and therefore they are adopting the dry process, which makes it white enough.

"It is not every mussel-shell that will strip well. They require one with a straight edge. The best come from Wellington, and Wi Tako on his recent visit brought them up a supply. A shell will not last more than two or three days, it then gets too smooth to strip, and is used only for scraping off the scull.

"I observed that Mrs. Tako had three shells for completing her work, and others always used a different shell for the scraping part of the process, and occasionally roughened the edge of the stripper, if it was not working well.

"The women use several of the sub-varieties indiscriminately; they will take any of those named by Wi Tako in his letter of the 19th December, viz., *Oue*, *Raumoa*, *Huhiroa*, *Ngutunui*, *Atiraukawa*, *Rataroa*, *Atewheke*, and *Tarariki;* but I could find no one who had an accurate knowledge of all these varieties. No one could decisively point out to me which were which, from the parts of the leaves that the women were working at; and whilst discussing the question, a boy who had heard what was going on, went off to the swamp, cut a bundle of leaves, and threw them down before us, when there was immediately a dispute as to what varieties they belonged to. It was agreed that W. Tamihana, who was looked up to as an expert, and an authority, should go with me and point out the different kinds. He was often puzzled, and more than once took two varieties out of the same clump and pointed out distinguishing marks which did not always agree. I took tracings of all the kinds he named, but I was not satisfied that he had entire confidence in his own discrimination. Several of the varieties are named by Mr. Kelly, Rev. Mr. Taylor, and others, but the descriptions seldom agree; none are cultivated here, and all must be stripped with a shell. I think it is probable that under cultivation they would improve into *Tihore*.

"The women prefer the *Oue* and the *Ngutunui*, the latter having a greater abundance of fibre, and the former being very white; the *Raumoa* is the most common about here. Wi Tako and all the natives agree in saying that this is a bad time of year to prepare *Phormium*, when the flower stalk is green. The fibre will strip out much easier when the stalks are dry. There is not much *Phormium* in flower this year in this district.

"It is evident from the colour of the 'scull' that is stripped away with the fibre, that the epidermis of the upper side of the leaf only appears green from the green tissue underneath, for it is in itself of a light buff yellow colour. The epidermis of the under side of the leaf is a decided green.

"4th January, 1871.—I went out to-day to see the party who started yesterday to work; there were nine women and two men, and they had bivouacked fully five miles from Waikanae. As we rode along, W. Tamihana pointed out several clumps of *Phormium* bushes, which the party had tried on their way, and which had not satisfied them; and it is plain that only a small proportion of the *Phormium* is suitable for the fine fibre; and, where they did fix on a good clump, they did not select one in twenty of the leaves that were on it. They choose fully matured leaves, which are quite perfect, and have no signs of decay. They had no preference for any one of the sub-varieties in particular. I enclose small samples of the several kinds, which they dressed for me, cleaning the fibre from the scull before it was dry. They show, as far as I can judge, that there is little or no difference in quality and colour.

"I don't think that this party of eleven natives will complete more than 50lbs. of fibre for their two days' work; but I could only form a very rough guess, from what I saw lying around them. They have no scales and weights themselves.

"Manawatu, 5th January, 1871.—The natives of Otaki are not preparing any of the fine flax; they think the price insufficient. I tried to induce T. Rauperaha to take it in hand; but he seemed to consider the attempt was useless. They are making a little at Waikawa, on the Ohau, some five or six miles further on, but I could not make any arrangement for the purchase of it, although I offered to take what they could get ready; they would not listen to £40 a ton, at which rate I told Rauperaha I was prepared to purchase. I did not go to the settlement, but several of the principal men were at Otaki. The Otaki natives maintain that there are but two kinds of *Phormium* growing in this district, *Harakeke* and *Wharariki*; and when I told them that a great many varieties were recognised by the Waikanae people, they said that it was only Ngatiawa 'gammon,' and that the *Oue*, *Ngutunui*, &c., were not to be had nearer than Taranaki, that it was all *Harakeke*. They are again stripping common *Phormium* for Mr. Bevan, at 1½d. a pound; and I enclose a sample stripped with a piece of iron hoop, which they use for their own ropes, halters, &c.

"Opunake, 18th January, 1871.—The natives at Opunake, after some consideration, declined to prepare any fibre on the terms made with Wi Tako and the Waikanae Maoris. They said that the work was too much, and the price too little; and moreover, that they had leased all their *Phormium* to the mills, and were busy making roads.

"They produced samples of fibre from eighteen different varieties of *Phormium*, and gave me the names. I tested their knowledge in various ways, until I tired their patience, and they refused to answer further questions, but asserted that there was no 'humbug.' They were, however, anxious to prove that there was no mistake about the names, and more than once sent the sample in question to another hut, where it was referred to an old woman, who was considered an authority in these matters. Mr. Kelly, M.H.R,, says that there is but this one woman in the whole district who has a good knowledge of the varieties.

"I offered them 6d. a lb. for the samples, which they agreed to take, but on finding that the parcel weighed only fifteen pounds, they refused to let it go for less than 10s., and, on my objecting, carried it off. I had to accede to their terms the next day, as I wished to get the samples for experiment and comparison.

"They consider the *Atiraukawa* the best plant in this neighbourhood, but I have come to the conclusion that the varieties of *Phormium* have different names in each district, for I could not find the descriptions agree either with what I had seen elsewhere, or with those given in the Commissioners' Report of 1869–70.

"There are no varieties cultivated in this part of the coast, and the natives all referred to Taiporohenui and Matangarara, in the Patea district, as the only places at which there are plantations. Ngahina informed me that they would be quite ready to prepare any quantity we might require *if they were allowed to go back to those settlements*—an inducement that is not likely to be accorded to them.

"13th June, 1871.—I have found it impossible to procure any fine dressed native *Phormium* from Waikato, Bay of Plenty, or Napier. The Maoris will not undertake the labour of preparing a large quantity. One of the replies from Waikato was, 'that they did not care about money now as it would not purchase arms and ammunition.'

"I set a native to work at some of the *Rataroa* growing near St. John's College. He was tolerably expert, and wasted no time, but barely managed to prepare two pounds weight in a day of eight hours. There was no difficulty in stripping out the fibre, but a great deal of time was occupied in completely removing all the vegetable tissue that remained attached to it. It was only the unblemished first pair of leaves, next the centre, that yielded a pure white fibre, all the others were more or less stained or discoloured,

"What they require for making their fine mats is so trifling in quantity that they will take any pains in preparing it, and they sometimes keep it for years to improve its colour and texture, placing a high value upon that which is very old; but to make several hundred weight would involve an amount of time and trouble that they do not care to encounter, unless guaranteed a remuneration far beyond its commercial value.

"There are no *Phormium* cultivations at the Native settlements in the immediate vicinity of Napier. What they want for the finer purposes is selected in the swamp by those who are skilled in the art."*

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* Commissioners, 1871.

CHAPTER VI.

European method of preparing the fibre.—Description of various machines.—Chief points to be attended to in the manufacture.—Oiling.—Sea damage.

"THROUGHOUT the Colony there has been one almost universal method of manufacture by Europeans, having for its object the production of fibre for rope-making. The green leaves are stripped by revolving rollers, with projecting beaters, travelling at a high rate of speed, which crush the epidermis against a fixed plate so set as to allow room for the fibre to remain intact. The fibre thus freed from the leaf of the plant, is washed by various methods, put on the ground or on lines to dry and bleach, finished by an arm or barrel-scutch, and when baled, is ready for market."*

"The machines used in the province of Auckland are of three kinds, made respectively by Messrs. Fraser and Tinne, of the Phœnix foundry, Auckland, Messrs. A. and G. Price, Onehunga, and by Messrs. E. Gibbons and Co., of Onehunga. All these machines are however identical in principle, and vary only in the details by which the principle is carried out. This principle is that the leaf is held between horizontal feed-rollers, revolving at a certain speed, while, as the leaf passes out from them, a drum, armed in its circumference with iron beaters, and revolving more rapidly than the feed-rollers, strips the epidermis and tissue away from the fibre, means being provided for adjusting the beating drum to a proper distance from the roller or bar against which the *Phormium* leaf is stripped, so that the leaf may neither, on the one hand, pass through without being crushed, nor on the other, have the fibres cut. Another contrivance common to all the machines is vulcanized india-rubber cushions or spiral springs placed over the journals of the upper feed-roller, so as to allow different thicknesses of leaf to be passed through.

"The first essential of a *Phormium* machine is, of course, the quality of the fibre it produces. This depends to a certain extent upon the shape and velocity of the beaters, but more particularly upon the ease and accuracy with which the machine can be kept in adjustment. The length of that portion of the tip of the leaf which is left undressed by the machine, depends upon the firmness with which the feed-rollers grip the thin point of the leaf, and the distance of the place where the leaf is crushed from the place where it is held by rollers.

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* Commissioners, 1871.

"We know that, on the one hand, simple percussion with a hammer on a block of wood, and on the other, scraping with a knife or shell, can each be made to yield good fibre, so that the limits of the speed at which the beaters strike the leaf, which is necessary for making good fibre, are probably very wide. The velocity with which the beater scrapes the *Phormium* is of course the difference of velocity between the beater and the leaf as it passes through the rollers; and as the blow is delivered not at right angles to the leaf, but at first at an acute angle, which rapidly changes to the same direction as the leaf as the beater passes round with the circumference of the drum, it follows that the greater the velocity of the beaters the more will their action be one of scraping, and the smaller the velocity the more will their action be one of percussion, or more properly detrusion.

"In Fraser's old machine, and in Price's smaller one, the beating drum is thirteen inches in diameter, armed with fourteen beaters, consequently, when making 1,260 revolutions a minute, the velocity of the beaters is 71·5 feet per second. The velocity of the circumference of the feed-rollers, or, in other words, the velocity of the leaf, is about 2·7 feet a second, thus leaving a velocity of 67·8 feet per second with which the beaters pass the leaf. In Gibbons' machine the beating drum is seventeen inches in diameter, armed with thirty-eight beaters, and revolves at only half the speed of that of Price's and Fraser's smaller machines, the feed-rollers of all moving with the same angular velocity. Consequently, when Gibbons' drum is making 630 revolutions per minute, the beaters have a velocity of 46·7 feet per second.

"The feed-rollers of this machine being slightly larger than the others, the velocity is 2·8 feet per second, making a velocity of 43·9 feet per second with which the beaters outstrip the leaf, so that the velocity of the beaters to the feed is as 1·17 in Gibbons', and as 1·26 in Price's and Fraser's old machines. In Price's and Fraser's old machines there are fourteen beaters on each drum, the feed-rollers are 2·5 inches in diameter, and the drum makes five revolutions to one of the feed-rollers, so that each blow of a beater is on an average (as the beaters are not equi-distant), rather more than one-ninth of an inch from the one before it. In Gibbons' drum there are thirty-eight beaters, the feed-rollers are 2·6 inches in diameter, and the drum makes two and a-half revolutions to one of the feed-rollers; consequently, each blow is delivered rather more than one-twelfth of an inch behind the former one, and the power saved is proportionately great.

"Notwithstanding these differences in velocity and in number of blows to an inch, we are of opinion that all the machines when in proper adjustment make equally good fibre. In Price's and Fraser's old machines the beaters were placed diagonally across the face of the drum, sloping alternately in opposite directions, and the spaces between them were filled with wood. Gibbons' new machine has the beaters set on the angle, but all running parallel, which allows them to be placed nearer together. In Price's new machine the drum is fifteen inches in diameter, with twenty-six beaters, which are of the same kind as in the smaller machines, but being placed closer together increases the rapidity of the blow. Messrs. Price tried the chevroned beaters, but afterwards abandoned them. In all these larger drums the wood between the beaters is omitted. We are of opinion that the position of the beaters on the drum matters but little as far as making good fibre is concerned, provided that the velocity is sufficiently great, and the striking edge of the beater round and smooth. It may here be remarked that Captain Hutton thinks that the beaters on the drum should be hard, but that the bar or plate against which the *Phormium* is crushed should be soft. Mr. Booth, of Dunedin, has endeavoured to carry out at least a portion of this idea, but has abandoned it.

"The adjustments of the different machines vary considerably, but all are capable, with more or less ease, of adjustment while the machine is in motion: a point of the greatest importance. In Price's machine the *Phormium* is crushed between the beaters and the lower feed-roller; and in his earlier machines the distance between the two was regulated by means of screws, which moved the journals of the beating drum forwards and backwards on a sliding bed; now the drum is fixed, and the whole of the standards carrying the feed-rollers is moved in the same way, which allows the feeder to adjust his own machine without moving from his place.

"In Fraser's new machine the *Phormium* is stripped against a thick plate rounded at the end, which is slipped under the feed-rollers; the back of the plate has a flange, which is pressed forwards by two screws against india-rubber, the elasticity of which pushes the plate back when the screws are loosened. This adjustment is very easily made by the feeder. In Gibbons' machine a round bar with square ends takes the place of the plate, and, being near the beating drum, it leaves very little of the leaf undressed. The adjustment is given by pinching-screws, which act through the boxes carrying the journals of the beaters.

"The wear upon both the surfaces of metal between which the *Phormium* is dressed is very great, while a very slight wear prevents the machine from dressing the *Phormium* properly, so that the surfaces have to be constantly filed up or changed. In Price's machine, the lower roller, against which the *Phormium* is dressed, is a cast-iron hollow cylinder. As their roller is three inches in diameter, and by constantly revolving always presents different surfaces to the beaters, it lasts much longer than any other of the machines; but when it is too much worn the machine has to be stopped, taken to pieces, and the old cylinder ground up, which is a work of considerable time, but they give a spare roller with each machine.

"In Gibbons' machine the round bar, having four-sided ends, can be shifted so as to show four different surfaces to the beaters as one after the other is worn out; it is then thrown away and a new one put in. It was at first thought that eight changes might be got from each bar by shifting it end for end, but this is not the case if good fibre is desired, and as the cost of the bar is trifling, there is no necessity for trying it. This bar can easily be shifted while the machine is in motion. As Gibbons has two machines on one shaft, the stoppage of one necessitates the stoppage of the other. In Fraser's machine no change of face can be obtained, but the worn plate can be slipped out, and another put in in a few seconds without stopping the machine, and the old plate can be ground up again, ready to replace the second, when it is in its turn worn hollow. The cost of these plates is also small, being only 2s. 6d. each.

"The importance of dressing the leaf out to the tip is considerable, as it prevents great waste. In Gibbons' machine, and also in Fraser's new one, the feed-rollers are deeply and sharply fluted, and hold the leaf firmly to the tip; the distance, however, to the place where the leaf is stripped is rather longer than in Price's, which, beating on the lower roller, reduces this distance to a minimum. On the other hand, the lower roller of Price's machine must be made smooth, as the *Phormium* is dressed on it, and so cannot take so good a hold of the thin end of the leaf, but allows it sometimes to be pulled through by the beaters. This can, to a certain extent, be remedied by the person feeding either twisting the thin portion of the leaf round his fore-

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finger as it enters the rollers, or by his 'tailing' the butt end of one leaf to the thin point of the one before it, and so increasing the pressure on it. This 'tailing on,' however, must not be overdone, as the leaves are apt to entangle with the 'out-taker' under the machine. Fraser's old machine had the fault of a smooth lower roller, combined with a considerable distance between the beating-plate and the feed-roller. In practice, when the machines are in good order, and working well, we are of opinion that there is little difference between Fraser's, Price's, and Gibbons' machines in this respect.

"Next in importance to the quality of fibre produced comes the quantity of green leaves passed through in a given time. This depends not only upon the diameter and velocity of the feed-rollers, but also upon the size and shape of the leaf taken through, the liability to stoppage by fibre getting round the shafts, and the ease of clearing the machine when choked. The diameters of the feed-rollers are nearly alike in all the machines, those of Gibbons' being the largest, and the comparative velocity can of course be altered to the wish of the manufacturer. It is easy to drive the machines fast, and the 'feeder' can put a large number of leaves through in a minute; but our experience is, that from thirty to thirty-five leaves a minute is quite as much as the 'out-taker' can manage without entangling or losing a large part of them, and it is in this direction that improvement is most required. It will be found that feeding at the rate of two and three-quarter feet per second will pass thirty-three average sized leaves through per minute, or a quarter of a ton per hour per machine.

"The size and shape of the butt of the leaf that the machine will allow through is important, for much time is lost when the machine refuses to take in big butts cut square at the ends, and it takes too long to go over all the leaves first and cut off the thick ends and point them, to say nothing of the waste of stuff that has been paid for. In this respect both Gibbons' and Fraser's new machines which have both feed-rollers fluted, have an advantage over Price's, the lower roller of which is compelled to be smooth.

"Stoppages are sometimes occasioned by *Phormium* getting round the shafts of the drum or feed-rollers, and into the bearings; but with the machines in good order, this now seldom occurs except through carelessness. As, however, it will, in spite of all care, happen occasionally, it is of importance that every facility should exist for clearing with as little delay as possible.

"In erecting machinery to be driven by steam, care should be taken that the machine-house and chimney or funnel should be so placed that the prevailing winds shall carry the soot, smoke, and sparks away from that part of the establishment where scutching and packing operations are carried on. Fire-protectors should also be placed on the top of the funnel. Want of attention to these matters has already been the cause of several fires.

"Care should also be taken that the scutcher shall be so placed that the prevailing currents of air through the mill, where no exhaust fan is used, shall take the refuse and dust away from those feeding the scutcher. With all possible care, the impalpable dust flying about will reach their lungs, and therefore a respirator, as already suggested, should always be worn.

"Where it is necessary to work the scutcher and to pack or bale at night, patent lamps should be used, as all unprotected lights are more or less dangerous."*

"An improved stripping machine which has been brought lately into notice is that of Mr. White, of Auckland; and, judging from the samples of fibre prepared by it, it deserves the attention of manufacturers, as it appears to clean the fibre without bruising or cutting it in the manner which is so frequently observed in the ordinary machine-dressed fibre, its action appearing to produce a result on the leaf more analogous to the scraping process of the Natives. The following description of Mr. White's machine is extracted from the 'Southern Cross,' of 25th April, 1871:—

'The process which forms the subject of this notice is one which commends itself to the favourable notice of *Phormium* dressers. It is a great improvement on many of the old machines, but whether in the right direction or not it is hard to say, as it is impossible to decide what the right principle of *Phormium* cleaning will yet prove to be; but it is certain that it will prove as efficacious as simple when once discovered. Some time ago we briefly referred to the existence of Mr. White's machine, but the invention being then unsecured, no description of it was published. By the last mail from the south Mr. White received the necessary documents to secure his right, and longer secrecy need not therefore be maintained. Yesterday it was set in motion, driven by a belt from the engine in Mr. Hawkeswood's foundry in Chapel street. The machine consists, first, of a strong wooden frame, upon which the moving portions are fitted. In front of the workman is an iron feeding mouth, about three inches broad by half an inch deep. This leads close to a pair of horizontal fluted feed-rollers, about six inches long. These work into each other, so that the *Phormium* blade is thoroughly bruised before it comes to the stripping horizontal cylinders, two in number, and which are immediately behind the feed-rollers. These cylinders are about six inches long, with an equal diameter. After being adjusted in a turning lathe, grooves are cut along their surface, about a quarter of an inch deep, and at an angle to the length of the cylinder of about thirty-five degrees. There are about three grooves to the inch, and the outer surfaces of the ribs thus left are about one-eighth of an inch wide. These cylinders are placed one above the other, and revolve outwards from the feed-rollers at the rate of about 2,200 per minute. The feed-rollers revolve at about one-eighth of this speed. Hence, after the leaf has been subjected to a thorough bruising by the feed-rollers, it is next subjected to the stripping action of the cylinders, which clears both sides of the leaf at once. Both cylinders have a slow reciprocating action, and thus the possibility of a hollow being worn out in the centre of the cylinder is prevented, the reciprocating action causing them to be worn evenly. When the angle ribs on the cylinder have been worn down the grooves can be re-cut, and any irregularities in the wearing of the cylinders removed in the lathe. Thus, at a small cost, partly worn cylinders can be made as good as new. The necessary gearing to produce the different motions, and the reciprocating action of the cylinders, is fixed upon the shafts of the two cylinders. Under each of the bushes of the lowermost feed-roller is placed a vulcanized india-rubber spring, so that the rollers bruise both thick and thin leaves of *Phormium* equally without injuring the fibre. After the *Phormium* has passed through this machine, it is put into one consisting of a pair of plain feed-rollers, and two circular hair-brushes. These strip off all the fleshy matter of the leaf which the ribbed cylinders have brought to the outer surface, and pass the fibre out very clean. The fibre is next passed between another set of plain feed-rollers, which guide it between two smooth cylinders, having a rapid reciprocating action. This is found to divide the fibre into very fine filaments, and to make it particularly soft. These two machines can keep four of the first kind in constant work. The fibre is next soaked in water for some time, then taken out, dried, baled up, and is ready for the market. This is Mr. White's whole process of *Phormium* cleaning. To many it may seem a somewhat cumbrous system, but it necessarily looks more so from a minute verbal description than seeing the process carried out. Although the cost of producing a ton of fibre by this process would be somewhat greater than by many of the more imperfect machines now in use, it will be seen that the cost cannot be very great when leaves travel through the machine at the rate of 200 feet per minute. It must also be remembered that *Phormium* dressed on this principle is valued at a high figure. By the last British mail Mr. White received advices from several extensive manufacturers in Scotland, to whom samples had been sent for valuation, stating that if *Phormium* equal to the samples sent could be supplied in quantity, it would readily sell at from £70 to £120 per ton.' "*

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* Commissioners, 1870.

The machine which performs the mechanical operation of scraping with least injury to the fibrous bundles, and in fact approaches nearest to the native method, is that recently introduced by Mr. Pownall, and which is described in Appendix IV. It is however considered doubtful whether this machine in its present form can clean the fibre with economy, on account of its slow motion, and the fact that only half a leaf is put through at once.†

A classification of the various machines which have been introduced for the manufacture of *Phormium* will be found in Appendix IV.

"The chief points in the manufacture on which the production of a good quality of fibre depends, appear to be as follows:—

"1. The careful selection of the leaves; which should, if possible, not be in any way damaged or decayed. In practice, after a mill has been established for some time, the leaves that have from fourteen to twenty months' growth will be readily obtained and found to be most profitable. When the loss of the best fibre by tow, which is incurred by the excessive scutching required to get rid of the 'croppy ends' and the 'straw,' is taken into account, it is a question whether it will not pay to split the leaves and strip off the midribs and hard margins. Neither should the strong butts ever be allowed to pass into the machine, as is too frequently the case, in the hope of getting a longer fibre, as the effect is to produce 'coarse red ends,' which materially deteriorate the value.

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* Commissioners, 1871.

† Might not this machine be improved by increasing the width of the scrapers, and feeding the whole leaf through an aperture shaped so as to gradually flatten it out as it approached the rollers? By this change the preliminary expense of splitting the leaves would be avoided, and twice the quantity of green leaf put through with the same labour and time as at present, and with only a slight proportional addition to the driving power.—J. HECTOR, April, 1872.

"2. Whatever kind of machinery is used it must be very carefully attended to, being kept clean and in perfect adjustment. The employment of a flow of water on the stripper has a very beneficial effect, both on the machinery and on the fibre produced.

"If Mr. Kelly's improved contrivance for effecting the adjustment of the ordinary scraping machinery while in motion, on which he is at present experimenting for the Commissioners, should succeed in practice, it will admit of the adjustment being rendered more perfect than is possible under any present arrangement.

"The use of a second stripper, through which the fibre passes direct from the first, facilitates the after treatment.

"3. Thorough washing of the fibre after it has been reduced to finely divided bundles, and immediately after leaving the stripper, is resorted to for the production of the best qualities. As any maceration is to be avoided which will tend to make the fibre soft and cottony, long soaking is not suitable; therefore, as the matter to be washed from the fibre adheres with considerable tenacity, mechanical force must be applied to effect the washing in a sufficiently short time.

"This constitutes the essential feature of wet-scutching, but none of the forms yet proposed for the application of this process are either perfect or admit of universal application. The error appears to be in most cases in applying too violent a force. When there is an abundant supply of water, and sufficient pressure, the method that appears most promising is to wash the hank in a strong jet with slight percussion. On the other hand, if water is scarce the amount of percussion must be increased, but in no case must the breaking up of the fibre be carried to an extreme.

"4. Bruising, excepting under water, and even handling of the liberated fibre, should be avoided as much as possible until it is quite free from the vegetable tissue. Rolling may then be used with advantage, but not till the washing is quite complete. The object proposed to be gained by rolling in this stage is not only to save time in drying, but also to consolidate and define the bundles of fibre. This latter point is a step in the process which does not appear to have attracted the attention it deserves. An examination of the native-dressed fibre shows that it is extracted from the leaves in long delicate bundles of great tenacity and strength; and when it is desired to make cordage these long fibres are kept distinct and prevented from fraying out by the application of a little oil. In the European method of preparing the fibre on the other hand, the action of the stripping machine is so imperfect as to leave adherent tissue, which experience has shown cannot be removed without washing, which process, however, tends to entangle the bundles and deprive them of the clean defined form which is so characteristic of the best roping fibres.

"5. The bleaching and drying of the fibre, if the washing has been thoroughly performed, will be effected with ease and rapidity; and in the Southern Districts especially, this is a point of great importance during the winter months.

"If a pure white fibre were required the sun bleaching might be dispensed with altogether, as purity of colour can only be obtained by thoroughly washing out the *bitter* principle from the plant. As already stated, however, washing to such an extreme degree is not desirable when the fibre is intended for the rope maker.

"The only course, therefore, is to employ the action of the sun to convert the residue of extractive matter that remains in the fibre into a form that is not prone to undergo further change.

"The effect of the sun's light is therefore to change the nature of the substance producing a yellow red tinge, that varies in depth with the amount of extractive matter in the fibre. The action of boiling water on *Phormium* is to darken this extractive matter to a grey tint, leaving it in the same condition as if it had been affected by the light. The macerating effect of the hot water on the fibre bundles is, however, prejudicial to the use of fibre thus treated for rope making.

"6. If the early stages of the process have been carried out in the above manner, the fibre will contain little that requires to be removed from it by scutching, which should therefore be performed rather with the view of burnishing the fibre than of reducing the quantity by the production of a large proportion of tow. It is the saving thus effected that must cover the extra expense for labour in selecting and preparing the leaves, and in thoroughly washing the fibre.

"Experience shows that the application of a small quantity of oil to the fibre not only improves its appearance, but also reduces its liability to undergo further maceration in water. The samples exhibited by the Natives of fibre prepared for making their fishing lines and other cordage, show that they appreciate the value of this application.

"Oil is used by the rope-maker to facilitate the spinning of the fibre, but the best time to apply the oil,—at least in the case of *Phormium* that is to be made into rope in the Colony—would be at a final stage of the scutching, as a much smaller quantity would then be sufficient. It may be suggested that after the dust and broken fibre has been removed from the hank, the fibre could be lightly varnished with oil in a second scutch, the beaters of which touch against a piece of felt passed through a slit in the roof of the box from a trough-shaped cistern of oil on the top. The kind of oil to be used is now being experimented on. Paraffin has been recommended by Professor Church; and some of the heavy petroleums, such as that singular form of Rock oil obtained at Taranaki, might perhaps be substituted for that substance with advantage. The Natives use animal oil, and the result, so far as yet ascertained, indicates that this kind will answer with certain precautions, and that it is at least much superior to the application of tar in any form, which has an action on the fibre like that of acids.

"When the fibre is intended for export in bulk, it is doubtful if the advantage derived from oiling before making it up into bales would be commensurate with the increased risk of combustion taking place in it, unless it were kept for a considerable time before being compressed; but, if the fibre is to be made up into rope in the Colony, there is no question of the great advantage which arises from applying the oil at this stage of the manufacture, and that rope so made will compete successfully with any other in the market.

"7. Experience has shown that iron lashings for the bales, whether in the form of wire or hoop iron, do not meet with favour in the market, and should not therefore be employed.

"Opinion now appears generally in favour of protecting the bales with covering of scrim or other light cloth, without which the wet, dirt, and chafing that occurs during the land carriage and whilst lying about on muddy wharves, cannot fail greatly to injure the fibre, and no doubt are the cause of much of the so-called 'sea damage' from which so many of our exporters have suffered.

"The sample bales of the fibres which compete with the *Phormium*, received from London, were all well protected by coverings, more care having been taken in packing them than is usual with New Zealand fibre. The Manilla bale was covered with matting made from the plaintain leaves, and this suggests that the cheapest form of bale cover for the New Zealand fibre might be made from the refuse leaves which are rejected in the process of manufacture.

"Adherence to one uniform size of bale is most important, and it is thought best to adopt the dimensions of a Manilla bale, which measures 3ft. 3in. x 1ft. 8in. x 1ft. 8in., and weighs about 2¼cwt."*

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* Commissioners, 1871.

CHAPTER VII.

Wet scutching.—State of the industry in the various districts in 1871.—Mills in operation.—*Phormium* as a roping material.

"ALTHOUGH it appears that no material alterations have been introduced in the various processes of manufacture since the year 1870, yet, as labour has become more skilled, and experience has suggested modifications in the machinery employed, there has been a marked improvement in the general quality of the fibre produced. This was readily observed by comparing samples from parcels which were sold during that year in London with others from bales that were more recently exported; and there can be no doubt that if all manufacturers could take advantage of every minor improvement that has been effected in different districts, they would still further improve the fibre, and diminish the cost of its production.

"The only important advance attempted is wet scutching, the effect of which in cleaning and softening the fibre is so marked that no part of the process of manufacture deserves more attention in order to perfect its application. Unfortunately, the usual mode of wet scutching has not been commercially successful. For although the fibre was by this means so much improved that local purchasers were ready to give £3 extra for the *Phormium*, yet the loss of fibre by the formation of an excessive amount of tow and the additional expense for labour, (which together caused an extra cost variously estimated at from £6 to £10 per ton) rendered the process an unprofitable one. The advantage of wet scutching is, however, so great, particularly in reducing the time required for bleaching, which is a point of the utmost importance in seasons when the weather is unsettled, that a further trial is strongly recommended.

"In Auckland, as in other parts of the Colony, a large number of the mills that were started a couple of years ago have been closed. In the Mauku and Waiuku districts, those that continued running were all worked by water power, as the extra expense of steam would have swallowed up the little profits that were still attainable.

"Price's and Gibbons' machines, with an improvement on the former by Dugald, were chiefly used, but there was a difference of opinion as to their respective merits. The plant is not abundant in this district, and the cost of the green leaf is correspondingly high; but there is sufficient for these small mill owners, who, working themselves, and with their families, and sparing no pains to produce a good article (for none other will sell at a remunerative price), can earn fair wages. Their fibre meets with a ready sale in Auckland to the rope spinners, or for export to Sydney, where a good deal is made use of, as much as £13,000 having been paid within the last three years by one firm for New Zealand fibre,—from £17 to £21 a ton being the prices given for favourite brands.

"At a mill in the vicinity of Napier a modification of the ordinary process was adopted. Steam power is used, and two of Price's machines were at work, a stream of water from artesian wells being kept running over the flax as it passed through. It is then squeezed through rollers, and washed and dried in the usual manner; the leaves are carefully sorted into three lengths, and the cost of a ton of ordinary fibre is about £15, exclusive of interest and management. About three tons have been further hackled, to test its value in the London market, but as twelve tons of leaf will only make one of hackled fibre, and one of tow, at an expense of £35, it is hardly to be expected that the sale will be remunerative.

"The only mills in operation on the west coast of the Province of Wellington were working on a small scale, steam being the usual motive power, as there is rarely a sufficient supply of water for the purpose of driving machinery in the vicinity of the raw material. In many cases the supply is even so short that there is not enough to allow of the fibre being thoroughly washed, which is a serious disadvantage to the manufacturer. Price's stripping machines are the most general in use, and are universally preferred in this district, as they are said to dress the fibre more evenly, although Gibbons' machine causes less waste. Wet scutching is employed only in one mill, owing to the deficient supply of water. At this mill, also, there being no screw press, a beam of wood thirty-six feet long is used for baling, a contrivance which is in common use in North America for compressing fur-bales, and might be usefully employed by small capitalists.

"There are several mills in the Wairau Valley, where there is abundance of raw material and water, but the manufacture has not been in all cases profitable. It has cost one mill-owner £20 a ton to produce eighty tons, including interest on capital; and as the fibre was not well washed, it would not rank above the second class.

"The fibre prepared in this district by Messrs. Logan and Sinclair, and by Mr. Goulter, deserves special mention, as having probably commanded the highest prices of any that has been placed in the London market. By both, Price's machine is used in the ordinary way, being driven by water power. Great care is taken in selecting the leaves, and water is liberally used in the washing process. The superiority is not attributed in any way to the raw material, but simply to the care and attention which is taken in every part of the process, and especially in the proper adjustment of the machine. The cost of the fibre delivered in Blenheim, ready for shipment, is stated to be £14 to £15 a ton; the prices it realized in London during the depression in the value of the fibre that was experienced in 1870 ranged from £31 to £36.

"At the mills at Leithfield, in Canterbury, wet scutching was adopted; the scutch having rounded wooden beaters revolving at a speed of 250 revolutions per minute, and not wasting much fibre, as 6½ tons of green leaf gave one of fibre. Another improvement is a travelling table that takes the fibre away from the stripper, which answers perfectly, as it saves labour, and permits a flow of water to be pouring over the fibre whilst being put through the stripper. Price's machines are preferred, and the cost of manufacturing one ton of leaf is estimated at £18; this includes the expense of the steam engine, which is £3.

"A modified process which requires notice is that of Mr. Journeaux, who prepares a very white and soft fibre, the cost of which he states to be £14 a ton. The leaves are first stripped, then retted for four days without the aid of heat, afterwards passed about 100 times through rollers in five minutes, while a copious flow of water pours over them.

"In Otago and Sonthland both steam and water-power was in use, and the machines preferred are those of Messrs. Kincaid and McQueen.

"For full particulars respecting the principal mills which were in operation in various parts of the country in the years 1870-1, the reader is referred to Appendix III., from which it may be gathered that *Phormium* fibre has only been produced with profit, when labour has been procured at a moderate rate, and when there have been the natural advantages of abundant raw material and water for motive power and for washing.

"The Manufacturer must bear in mind, that a good price is only obtained for the produce when every part of the process is carefully conducted, and when there is no false economy of labour, or undue haste in conducting the manufacture.

"The very best parcels which have been sent to England, and which realized the highest prices in the London auction rooms, have generally been prepared by men of small capital, who, producing only a limited quantity, have found the necessity of minute care and attention to every detail. Experience has shown that under favourable circumstances, and with water power, the best description and quality of fibre can be prepared ready for delivery at the mill at a cost of £14 a ton. And, if this can be done on a small scale, much more should it be practicable when large operations give scope for systematic and economical division of labour.

"During 1871 experiments were instituted to ascertain the relative durability of ropes made from *Phormium* and other fibres in common use, and the results, given in Table I. on page 47, show that the New Zealand white rope when kept dry will last longer, and wear 60 per cent. better, than tarred rope of the same material, and 34 per cent. better than rope made from Manilla hemp.

"When the ropes are wetted with salt water, however, the result of the comparison is very different. The lasting quality of the Manilla being actually improved, no doubt in consequence of the shrinkage, equal to 5 per cent. which takes place.

"On the other hand, the effect of the salt water on the *Phormium* rope is to reduce its lasting qualities 34 per cent.

"The ropes used were run over pulleys fixed on a horizontal shaft at Messrs. Kebbell's mill, and through a block below, to which a 56lb. weight was attached. The pulleys had a circumference of 15¼ inches, grooved out to a diameter of 2½ inches.

"The ropes were wetted with salt water poured on them till they would absorb no more, and the wetting was repeated every fourth day, when the ropes had apparently dried.

"The *Phormium* ropes were machine made, from Lloyd's Steam Rope Works, near Auckland, and are valued at £45 per ton. The Manilla rope was purchased in Wellington, and was the best of the size that could be procured.

"Rope made at Canterbury from *Phormium*, dressed with black oil, has lasted well on board coasting vessels, and has evidently a great

TABLE I.—RESULTS of EXPERIMENTS made to ascertain the relative DURABILITY and WEAR of PHORMIUM and MANILLA ROPE.—Wellington, March and April, 1871.

Description of Rope.		Circumference before experiment.	Length.				Weight.			No. of days run.	No. of miles run, at 4575 feet per hour.	Durability, per cent.
			Before experiment.	After experiment.	Per centage of Stretch.	Per centage of Shrinkage.	Before experiment.	After experiment.	Per centage of loss or gain.			
		inches	ft. in.				ozs. drs.	ozs. drs.				
Dry	*Manilla*	1·43	17 8	...	2·6	...	Not	accurately	noted.	20	173·3	100
	Phormium (white)	1·56	18 3	...	3·5	...	13 10·8	10 14·2	-20·3	28	242·6	134
	„ (tarred)	1·56	18 4	...	7·6	...	16 2·4	15 8·9	-00·3	15	129·9	74
Wet	*Manilla*	1·43	18 2	...	1·9	11·0	Not	accurately	noted.	22	190·6	110
	Phormium (white)	1·56	18 2	...	6·1	6·0	13 9·9	12 3·8	-10·0	20	173·3	100
	„ (tarred)	1·56	18 1	...	7·9	3·8	16 14·8	17 0·4	+00·6	19	164·6	95

TABLE II.—EXPERIMENTS IN 1872.

		Circumference before experiment.	Length before experiment.	Length after experiment.	Per centage of Stretch.	Per centage of Shrinkage.	Weight before experiment.	Weight after experiment.	Per centage of loss or gain.	No. of days run.	No. of miles run.	Durability, per cent.
		inches.	feet.	ft. in.			lb. oz. dr. gr.	lb. oz. dr. gr.				
Dry	*Manilla*	2	16	17 5½	9·1	...	1 9 11 30	1 9 0 0	- 2·8	39	337·9	100
	Phormium, native-dressed ...	2·25	16	19 5	21·4	...	2 1 1 5	1 13 4 0	-11·5	57	493·8	146
	„ machine-dressed* ...	2	16	18 6½	15·9	...	1 8 6 0	1 7 0 0	- 5·6	64	535·4	159
	„ „ (oiled)	1·62	16	18 10½	18·0	...	1 5 8 0	1 2 13 0	-12·5	92	797·1	236
Wet	*Manilla* †	2	16	17 4	8·3	8·6	1 10 2 30	1 12 0 0	+ 7·0	30	259·5	77
	Phormium, native-dressed... ...	2·25	16	20 9	29·7	7·3	2 1 0 0	1 15 9 0	- 4·3	22	191·0	57
	„ machine-dressed* ...	2	16	18 2½	13·8	8·6	1 9 10 0	1 9 8 0	- 0·5	22	191·0	57
	„ „ (oiled)	1·62	16	19 10	23·9	3·0	1 4 8 5	Still run	ning	118	1022·4	303

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* This was made expressly for experiment. Mr. Kebbell remarks that it was "got up in the best manner, and felt as if a small amount of some kind of grease had been used in the manufacture. This might account for the dry line running seven days longer than the dry native-dressed."

† "The Manilla was from a piece of whale line, apparently of the best quality. I think it ought to have been respliced and run again."

power of resisting wet. Plain New Zealand rope, used by Messrs. Stonyer & Co. in a Californian pump, that was constantly in the water, would not last more than seven or eight days; while Manilla rope would run for twenty; but a piece of the oiled *Phormium* rope under the same conditions did not give way till it had been ninety-five days in continued wear."*

This observation led to a second series of experiments being undertaken by Mr. Kebbell in order to test the relative durability of rope prepared with oil, and the results given in the second part of the table on the previous page so far confirm the importance of the application of oil to the rope, as it appears to increase its lasting power to an extent that is hardly credible. An inspection of the oiled rope that has been running wet and dry for 118 days shows it to be quite sound, and so compact on the surface that the water does not readily penetrate it.

Two tarred lines of *Phormium*, similar to the oiled lines, were tested, both wet and dry, at the same time, but gave way, one in two days and the other in three, the fibre having evidently been injured by the application of the tar.

" In the second series of experiments the weights attached were in proportion to the sectional area of the ropes; 56lbs. for a 1·56 inch rope having been used in the first series.

It should be stated that all the specimens of rope which have been experimented on by Mr. Kebbell are preserved in the Colonial Museum.

"As bearing on the question of the relative durability of rope made from New Zealand and other fibre, we have the distinct evidence of Commander Lewis of the U. S. steamer 'Resaca,' that *Phormium* rope which had received a slight dressing of whale oil in the manufacture, and which was rove off for tacks, sheets, staysail haulyards, jib-sheets, whips, &c., on a wet and excessively stormy voyage from Auckland to Valparaiso, lasting 54 days, was considered by the master of that vessel fully equal to any Manilla he had ever used.

"Captain Manning also reports in December, 1870, 'that some 2½ and 3 inch rope made from *Phormium* was used as burton-falls in taking in the cargo (1,200 tons weight and measurement) of the 'Dragon,' and that on the completion of her loading he found it nearly as good as new and quite fit to take in another cargo, which is most unusual. It appeared to stand the friction of lowering goods better than either Manilla or hemp. It could not have had a fairer trial, as during the whole of the ship's loading it was exposed to extremes of wet, frost, and snow, which did not cause any alteration in its appearance, as it neither swelled nor got 'long-jawed'; nor was the lay of the rope disturbed as is generally the case, more especially with Manilla; in fact it stood the hard work better than any rope he had ever used.'

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* Commissioners, 1871.

"These very favourable opinions are confirmed by an inspection of ropes exhibited in the Colonial Museum, which were used on board the ship 'Crusader' during a voyage from London to Lyttelton in 1870–1, the largest for discharging cargo, and the smaller for braces and haulyards. To all appearance they are still quite good and sound.

"From the evidence which has been obtained relative to the *Phormium* fibre as at present prepared for rope making, confidence is felt that it has now secured a permanent hold on the market at a remunerative value, which will probably rise as shipments of the fibre become more uniform, and its valuable qualities are better appreciated. It also appears that the failures hitherto in the attempt to make it a profitable industry, have not arisen from any fault inherent to the plant, but from the want of experience on the part of many of those who embarked in the manufacture."*

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* Commissioners, 1871.

CHAPTER VIII.

Competing fibres.—Culture and preparation of Manilla.—Fibre market in America.

Particulars concerning the fibres with which the *Phormium* will have to compete in the market as a roping material cannot fail to interest the New Zealand producer, and on this subject reliable information was obtained by the Commissioners of 1871:—

The competing fibres, with the prices of each in February, 1871, are as follows:—

"1. Russian Hemp; prepared from *Cannabis sativa.* Price of this sample in London, February, 1871, 34s. 6d. per cwt. Auction price in London, February, 1871, £31 to £39 per ton.

"Imported into England in—

"1868	...	Tons	23,754	Average price,	£37	9s.
"1869	...		28,180	„	32	18s.
"1870	...		30,641	„	33	0s.

"2. Italian Hemp; prepared from *Cannabis sativa.* Price of this sample in London, in February, 1871, 41s. 6d. per cwt. Auction price in London, in February, 1871, £37 to £44 per ton.

"Imported into England in—

"1868	...	Tons	12,275	Average price,	£36	15s.
"1869	...		11,253	„	40	19s.
"1870	...		10,433	„	42	4s.

"3. Bombay Hemp; prepared from *Crotalaria tenuifolia.* Price of this sample in London, in February, 1871, 27s. per cwt. Auction price in London, February, 1871, £17 to £25 per ton.

"Importations of East India Hemp into England—

"1868	... ...	Tons	989	Average price,	£28
"1869	... ...		2,142	„	25
"1870	... ...		2,179	„	24

"4. Sisal Hemp, prepared in Yucatan, from Henniquin—*Agave sisalana.* A native can prepare 6lbs. in one day. Price of this sample in London, February, 1871, 48s. per cwt. Auction price in London, in February, 1871, £46 to £48 per ton.

"5. Egyptian Flax; prepared from *Linum usitatissimum.* Price of this sample in London, February, 1871, 55s. per cwt. Auction price in London, in February, 1871, £40 to £48 per ton.

"6. Aloe Fibre; prepared from *Agave americana* or *Agave vivipara.* Price of this sample in London, February, 1871, 22s. per cwt. Auction price in London, February, 1871, £18 to £25 per ton.

"7. Manilla Hemp; prepared from *Abaca* (*Musa textilis*), of the Philippine Islands. Price of this sample in London, February, 1871, 56s. per cwt. Auction price in London, February, 1871, 46s. to 80s. per cwt., according to quality.

"Imported into England—

"1868	...	Tons 8,756	Average price,	£47	8s.
"1869	...	4,632	"	52	19s.
"1870	...	6,467	"	54	16s.

In forwarding the fibres, Messrs. G. and J. A. Noble supplied the following information:—

"With regard to Nos. 1, 2, and 3: these, it will be seen, are entirely a different fibre from that of the New Zealand, or *Phormium tenax.* Nos. 1 and 2 are occasionally used to supplement flax for linen, and largely for heavier fabrics of the same class, but No. 3 is only used for common cordage, and will always have considerable influence on the value of the lower qualities of *Phormium,* these being adapted to the same purpose.

"No. 6. Aloe fibre.—This will come largely into competition with *Phormium,* but from being badly cleaned it has hitherto not taken its proper position in the market.

"Nos. 4 and 7.—Sisal and Manilla hemp are the most important to keep in view in preparing *Phormium,* and the nearer this fibre can be brought to the quality of these two hemps the larger the consumption will become.

"There are finer qualities in Manilla, Italian hemp, and Egyptian flax, but these samples represent good average qualities, and such as are used in the largest quantities.

"The prices are generally higher than the average, particularly the Manilla and Sisal hemps, both of which have declined since these sample bales were purchased—the former £3 per ton, the latter £5 per ton. The other samples are £2 to £3 per ton higher than we should give for a parcel, as we were obliged to take them from different dealers, as importers would not break a parcel to give off sample bales. This difference in price arises from the quality of the fibres and the purposes to which they are severally applied; in all cases, the freer from refuse the more valuable the fibre."

In Appendix II., Table C., will be found a statement of the quarterly average prices of the competing fibres.

Among the above mentioned fibres the only real rival of *Phormium* is Manilla. Their similarity in appearance, and the fact that the price of *Phormium* in the London market is to a great extent dependent on the supply of the latter fibre, rendered it desirable to procure as accurate information as possible with regard to it. The following account of its preparation and culture, furnished at the request of the Commissioners, by Mr. J. S. Ricketts, H.B.M. Consul at Manilla, is accordingly given.

" *Culture.*—The Manilla hemp (*Abaca* of the Natives of the Philippine Islands) is made from the fibre of a species of musa or plaintain, called *Musa textilis.* It gives a large quantity of seed, and its leaves are more pointed and of a somewhat darker colour than the common plaintain tree. It is mostly propagated by transplanting its offshoots, which are numerous.

"In some places the fruit of this tree is bitter and not edible, in other places it is eaten by the natives; there would, therefore, appear to be more than one sort of musa from which the hemp is collected. It is, generally speaking, planted on the slopes of hills, and requires some little shade and plenty of moisture.

"The trees are planted from six to eight feet apart, the earth being well heaped up on the roots. At the end of the third year, previously to bearing fruit, the hemp tree is cut down and the fibre extracted.

"A full sized tree gives, I am told, from one to one and a-half pounds of hemp. Too rich a soil is not good for this plant, and tends to the growth of the leaf and the diminution of the fibre.

"This 'musa' is found in nearly all of these islands, and I have seen it growing wild in many places in the interior: it is also to be found in Java and Borneo.

" *Process of Manufacture.*—Numerous inventions have been made for the purpose of working up this fibre, but none of them appear as yet to have met with any success: indeed the hemp still continues to be produced by manual labour.

"Immediately the tree is cut down it is stripped of its linings; these are then cut into pieces three or four inches wide: on this they are drawn underneath an instrument resembling a saw fixed in a block of wood. The fleshy part of the cortex is thus scraped off and the fibre alone remains; this is then placed in the sun to dry.

"Two persons, one engaged in cutting down the trees and stripping them, and the other in extracting the fibre, can work up some twenty-five pounds of clean hemp in the course of one day.

"In some places the hemp is cultivated on the *Metayer* system, the workmen receiving one-half the quantity produced; in others, and indeed generally speaking, it is brought to market by peasant proprietors.

"Supposing that two persons are able to produce 25lbs. of clean hemp per diem, we have, if they labour twenty-four days in the month (and the natives seldom work more than this), 600lbs., or about 4½ piculs* as the produce of their labour during that time. The land in most places being but of a nominal value, the actual cost of production would be little more than the value of the labour. Now, taking this at $5 a head per month, the cost of production would seem to be about $2 : 22 cents. the picul.

"Money wages are never paid in the hemp districts; the labourer generally receives half of the hemp produced by him.

"The cost of maintaining a native may, including taxes, be calculated at about $5 a month as above mentioned.

"*Prices of Hemp.*—When at Manilla the market price of hemp is $8 the picul; at the port of shipment in the hemp district it is about $6½; and if some distance in the interior, $4 or $5. In the year 1861, the price of hemp in Manilla was as low as $2 : 73 cents. per picul; the natives at that time could not have obtained more than $1 : 87 cents.

"Hemp now sells at Manilla at $9 per picul, and during the last year its average price was $10. The natives here labour to obtain the mere necessaries of life, with which they are content; having obtained these, they manifest no regard for the future, and express no desire to accumulate. Hence, high prices do not, as in other countries, call forth an additional supply.

"Should any machinery be able to be invented capable of supplying the place of manual labour in the extraction of this filament, the exportation of the same from these Islands would soon receive a considerable increase, for it must be borne in mind that the limited quantity of hemp produced is due solely to a scarcity of the labour necessary for the process of its manufacture, and not to any scarcity of the plant.

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* A picul is equal to 133⅓lbs. avoirdupois.

"It is worthy of observation that the centre of this musa yields a very fine fibre, which is used for the manufacture of a texture, much valued by the natives, and called 'Sinamay.' The fibre takes also a blue and red dye; the latter is obtained from the use of the leaves of a plant called 'Payonguit' and the former by the application of the root of the *Morinda* mixed with a little lime."*

The chief market for Manilla, Sisal, and other fibres from which "white rope" is manufactured is in the United States of America; and in 1871 the Hon. Mr. Vogel made personal inquiries in that country respecting the prospects of *Phormium* being able to compete successfully with these fibres. From the notes of his interviews with the leading manufacturers it appears that "in New York the fibre is well known to ropemakers, dealers in flax, hemp, &c. Samples were frequently produced, but, as a rule, they were not good. The fibre has been generally imported from England, but some dealers spoke of direct importation as within their knowledge. As a rule, the New Zealand fibre is considered here not fit to compete with average Manilla; and samples of Sisal, of good quality, as well as various hemps, including some American grown, were during the inquiries shown by dealers as articles which would be preferred to the New Zealand *Phormium* for use with or as substitutes for Manilla.

"The present sale price of Manilla is about £42 per ton. During the war, and even since its close, the price has ranged from £55 to £76 per ton, but that average was spoken of as 'altogether unhealthy,' and as preventing a free use of the fibre. Some years before the war Manilla fetched no more than £21, and an old practical ropemaker expressed the opinion that for a steady market the fibre ought to be little, if at all, above £25 per ton.

"Reference to the price of Manilla was necessary, because every person who was consulted stated explicitly, or clearly implied, that that is the standard fibre for ropes, cords, &c., and that its price must rule the prices of any others introduced. At the same time, almost every person consulted spoke of the fluctuations in the price of Manilla.

"One of the samples of *Phormium*, prepared by Natives of the Wellington Province, was exhibited during the inquiries. Invariably, this fibre was most highly praised; and, without an exception, the reports declared that if such an article could be had in quantity, it would certainly realise, at any time, as much as good Manilla.

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* Commissioners, 1871.

Amongst the opinions expressed were, 'It is the very best fibre I have ever seen;' 'It ought, in time, to beat Manilla out of the market;' or 'It should compete with the best selected Manilla.' The practical head of a rope-manufacturing establishment (Mr. Marshall, of L. Conterbury and Co.), which was stated to be about the largest in the United States, after he had examined the same sample, declared, 'This would make the very best rope known. It would rank up to first-class Manilla,' and he was sure that a responsible firm in New York could be easily found to contract to make one thousand tons yearly, if it could be put down in New York for £42 per ton. A year ago, fibre equal to the sample would have fetched £55 per ton."*

Although these very satisfactory expressions were respecting a fair sample of Native-dressed fibre, that could not be produced either in quantity or at moderate cost by the method employed, they show, at the same time, that it is only improvement and care in the manufacture that is required to develop a quality of *Phormium* fibre that will be appreciated in the market. Experience in the market, gained since these opinions were expressed, have tended indeed to show that the peculiar flocky character of the Native-dressed fibre is rather against its application to ropemaking, and that with the careful adoption of the most recent improvements for such purposes, machine-dressed *Phormium* can be made that will command a better price than Native-dressed.

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* For the remainder of Mr. Vogel's memoranda on this subject the reader is referred to page 13 of the Appendix to "Report of Flax Commissioners, 1871."

CHAPTER IX.

Microscopical and Chemical Properties.

BEYOND the mere testing of the comparative strength of the *Phormium* fibre, and the ascertaining of the nature of the constituents, etc., of the plant, no investigation of its properties appears to have been made public till that undertaken for the Commissioners of the New Zealand Exhibition of 1865, of the results of which the following is an abstract:—

"*Mechanical Preparation.*—It was found absolutely necessary to commence the process by bruising the leaves. The leaves chosen were about seven feet long, from old plants, and the whole of the leaf was taken except about one foot of the base. The double leaf was placed upon a smooth block of hard wood and smartly struck over every part with a hammer, the iron head of which had its flat striking part rounded off at the edges to prevent the cutting of the fibre. By this process the bundles of fibres in the thick part of the leaf are easily separated from each other, but the top part of the blade, from its thinness, is much more difficult to break up.

"The nature of those two constituents of the plant which are supposed to interfere most with its preparation was first examined into.

"*Bitter Principle of Plant.*—This was found to be a non-nitrogenous, non-crystallizable body, of a pale yellow colour, feebly soluble in water, more soluble in alcohol, and capable of being absorbed by charcoal, and from which it can be dissolved away by alcohol. It refuses to form salts with acids or bases—it has all the character of a neutral substance. It is entirely removed by the repeated washing of the bruised leaf in water. In its concentrated form it is a very pure and intense bitter, and might be used, perhaps, to communicate a bitter taste to beer, in the absence of hops. It would at least be less objectionable than drugs that are said to be used for this purpose.

"*Nature of Gummy Part.*—Soluble in water, but very slightly so when cold, and unless the solution is very much diluted, it thickens, on cooling, to an opalescent jelly. It is insoluble in alcohol; also in aqueous solution of caustic or carbonated alkali, or solution of soap; indeed a clear solution of gum is rendered turbid and thick by either of these. On the other hand, it is readily soluble in sulphuric acid, strong or dilute, a thick opalescent mixture of it with this acid quickly changing to a limpid and nearly transparent solution, the whole of the gum being dissolved with the exception of a few flakes of some gelatinous substance which floats freely about in the liquid, and which are probably nitrogenous matters. In its chemical character and physical properties it much resembles gum arabic. When once dried or merely desiccated in a natural way, it is only partially soluble in water, at least it is only soluble with great difficulty, and when in this dry state it is very hard and brittle; probably it is this circumstance that tends greatly to injure badly prepared *Phormium*, the delicate fibres of which must be cut as with a knife by such a substance when they are twisted about in the process of manufacture.

"The action of various chemical agents upon the leaves of the plant is found to be as follows:—

"*Action of Sulphuric Acid.*—Three ounces of the bruised leaf were warmed up with twenty ounces of water, and two grains of concentrated sulphuric acid, previously diluted with water, were added. But this quantity was found insufficient to produce any result, even on long boiling, and the quantity of acid had to be increased to eight grains before any decided effect took place. With this quantity the green colour of the leaf was turned brown, and the solution also was coloured. Other three ounces of the leaf were therefore taken and treated with eight grains of sulphuric acid as before, and after boiling the whole for two hours, it was found that every part of the leaf was easily scraped clean by the nail, and the fibre did not appear to be damaged; it was, however, very harsh and inflexible.

"Further experiments proved that if the boiling process was kept up much longer, or if the amount of acid added to it was largely increased, the fibre was greatly damaged.

"*Action of Hydrochloric Acid.*—Hydrochloric acid was then substituted for sulphuric, with precisely the same results.

"The effect of an organic acid was next studied.

"*Action of Oxalic Acid.*—Oxalic acid was selected, as, from its being in a solid form, more exact quantities could be employed. 1,516 grains of the leaf were placed in twenty ounces of water, and boiled with twenty grains of crystallized oxalic acid, and digested for three hours, when the leaf was so much affected that it was easy to scrape it clean with a blunt instrument. This treatment did not impair the strength of the fibre at the time, though afterwards its strength seemed to decrease.

The fibre obtained was bright and lustrous, and of a grey colour, but still harsh and inflexible, and, as was the case with the mineral acids, an increased quantity injured its strength. It was therefore evident that the use of organic acids possesses no special advantages over that of the cheap mineral acids.

"*Action of Alkalies.*—1,120 grains of *Phormium* were put into thirty ounces of water, and one per cent. of caustic potash added, and the whole warmed for four hours, or until the leaf would scrape clean with the nail. In this case, though the fibre was clean it was very tender, and no matter how the quantities were varied, no useful result was obtained, for simultaneously with the cleansing of the fibre, there was a weakening which could not be avoided. The same results were obtained when carbonate of soda was substituted for the potash.

"These results are difficult to reconcile with what is said about the non-detrimental effect of stronger solutions of the alkalies, than those employed as above, upon linen goods in the process of cleansing them for the bleacher, but probably the fresh fibre of plants is more easily affected by the action of alkalies, than the same fibre after passing through the various operations used in preparing it for the manufacturer.

"*Action of Oil.*—The dry leaf was heated with it for some hours, but no advantage was gained, the leaf remaining unaltered.

"*Action of Alcohol.*—The high price of this re-agent would of course prevent its use, even if the re-distillation of it from waste solution for further use was resorted to.

"An unbruised leaf was found to be merely discoloured by the loss of its chlorophyll, the external varnish being first removed, nor was the bruised leaf more favourably affected, the gum, as before stated, being quite insoluble in alcohol.

"*Action of Soap.*—The last chemical experimented with was soap, its solvent powers upon many fatty and resinous substances being well known, and also the unsparing manner in which it is used upon many delicate fabrics without injuring them.

"A certain portion of the bruised leaf was taken and digested in hot water for two hours. It was then boiled two hours longer with 12 per cent. of common soda soap, before it affected the leaf so that it would clean with the nail. The fibre so obtained, when scraped, appeared to be everything that could be wished for, being remarkably soft and flexible, but with a faint shade of green colour, indicating probably that no decomposition of the fibre had taken place. When the sample of fibre so prepared had been kept for one year, it appeared to be equally as strong as at first; and indeed *Phormium* so prepared four or five years since still remains unaltered from the state it was in when first dressed.

"A much larger quantity of soap did not hurt the fibre, hence its use is free from those objections which attach to the use of acids or alkalies. The high price of the soap, however, would entirely prevent any adoption of this process, as it would entail a cost of twenty pounds upon every ton of clean fibre. The expenditure of soap, however, can be greatly reduced in two ways. 1st. By washing the *Phormium* repeatedly in warm water, and then adding the soap to the necessary amount. 2nd. Before adding the soap, by neutralizing with carbonate of soda the water in which the *Phormium* has been boiled, as it acquires an acid reaction. In each case the proper quantity of soap is that which gives to the warm solution a permanent froth upon its surface when stirred about. The first process of washing is preferred on account of its greater cheapness, and also because it avoids the danger of using the excess of alkali to which the latter is subject. In regard to the second process, the quantity of alkali necessary will vary with the season, but, at the time of the experiment (autumn), 3·5 per cent. of common washing soda, or 1·3 per cent. of the dry carbonate of soda was found to neutralise the acid substances of the *Phormium*. In either case about one or two per cent. of soap would be necessary. The cost of chemicals would be £4 to £5 to produce each ton of clean fibre by the first process, when soap is used alone; and by the second or neutralizing process, about £6 or £7. As will be inferred, an abundant supply of hot water is necessary. Perhaps the readiest and most economical way to maintain this would be to connect the steam pipe of a boiler with a perforated coil lying at the bottom of the vat or tub in which the operation is carried on.

"*Fermentation.*—It has been thought by some that possibly *Phormium* might be worked profitably for alcohol; but as it was found to contain but 1 to 1¼ per cent. of sugar (grape sugar), even in the autumn, it would not answer at all for this purpose. It was, however, attempted to turn this process to account in the manufacture of prepared fibre in the following manner:—The bruised *Phormium* was treated with hot water, and allowed to steep therein for three hours at 130°; sulphuric acid in the proportion of two grains to the ounce of *Phormium* being previously added to facilitate the change of the gummy matters, starch, &c., into sugar; the object being to insure a good and rapid ferment, in order to break up the cells of the plant, if such was possible. The whole was then cooled down to 80 °, and yeast added; fermentation soon commenced, and went on pretty fast, but when completed the fibre was found to be still difficult to clean, although considerably altered.

"The liquor from the preceding experiment was perfectly clear, of a pale yellow colour, and had to a remarkable extent the odour of bitter beer, and undoubtedly a kind of beer could be made from a strong infusion of *Phormium* mixed with a moderate quantity of sugar, and then fermented.

"*Retting.*—The last process tried was retting, to which process the varnish on the outer part of the leaf has hitherto proved an insuperable obstacle.

"It was thought, however, if the leaves were first broken up by rollers or stampers—or, still better, by a comb with teeth set wider in the back, so as to separate the leaf into filaments without any bruising —so that the gummy matters which bind together the *Phormium* fibres could be placed at once in direct contact with water, these would soon enter into a state of decomposition, and communicate this to the more inert portions of the plant, and which, if stopped before it had extended to the fibre of the *Phormium* by its removal from the solution, would give us a product as nearly similar as possible to the home flax, just after retting, and consequently in a fit state to be scutched, with its natural strength of fibre but little affected. Several experiments were therefore made to test this, and some of the results certainly appeared to be very favourable.

"*General Remarks.*—On reviewing these experiments we find that acids generally have the property of rendering the gummy matter which binds the fibres together soluble; but, though this makes the leaf more easy to clean, still there is always a hardness and an inflexibility in the fibre so prepared which must prevent its adoption. In addition, there is a danger of hurting its strength, and, unless washed with great care, the result would be its gradual deterioration.

"Oil, as might be expected, has little or no action. Alcohol, even if it could be economically employed, is useless, as it exerts no decided action upon those substances which have to be removed.

"The use of caustic, or carbonate alkali, alone, though very beneficial in some respects, is very objectionable in others. They enable us to clean the fibre with ease, but at the same time they impair its strength, always imparting to it a brownish tint, which can scarcely be looked upon as other than a sign of decomposition.

"In the use of the last chemical experimented on—soap—we have all the advantage obtained by the use of the alkalies above without their disadvantages; but the high price of this article would prevent its adoption for this purpose if used alone. If, however, as before stated, the acid of the *Phormium* was first neutralised with carbonate of soda, the use of a small quantity of soap would effect the rest without incurring the least danger or adding much to the expense of the operation. The fibre obtained in this way is easily cleaned, is not discoloured, and appears as strong as that prepared without the use of chemicals.

"The only remaining process requiring comment is the modified retting process, and which, in our opinion, is likely to be the most promising, as it involves no expense in chemicals, and but little in fuel. When properly performed it will, without doubt, give results equal to those obtained by any of the other processes, and in one respect superior, the woody tissue which binds the fibres together in bundles being in this case so much affected by the decomposition of the gummy matter, that it offers little impediment to the splitting up of these coarse fibres into hair-like filaments by the hackling machines."*

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* Hector and Skey, 1864.

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CHAPTER X.

Microscopical and chemical properties—(*continued*).

The next investigation was that made with regard to the structure and colour of the *Phormium tenax*, by Mr. T. Nottidge, of Christchurch and read before the Philosophical Institute of Canterbury on 1st September, 1869:—

"* * As is well known to all botanists, the fibre of the *Phormium tenax*, is the woody tissue or pleurenchyma of the leaf. This woody tissue consists of cells very much elongated, and tapering at each end, arranged side by side in bundles, the ends of the proximate cells overlapping.

"When the carefully cleaned fibre is teased out with a needle, and examined under a microscope by reflected light, with a power of 120 linear, it appears to be white and transparent, like filaments of spun glass, and where it lies in bundles it has a lustre like satin.

"When mounted in 'Deane's gelatine,' and examined by transmitted light with a power of 225 linear, the ultimate fibres appear to be cylindrical tubes of considerable length (probably one and a-half to two inches, but I have not succeeded in tracing any one cell through its whole length), the margins extremely smooth and regular, the finest of the fibres quite as fine as the silk of the *Bombyx mori*, or mulberry silkworm. The cells taper gradually to each end, and are slightly rounded at the point. A central canal of considerable size is plainly visible. I observed no transverse or longitudinal markings on the fibre. The central canal appeared to be filled with air only, when I examined the fibre in August, but this may not be the case at all seasons of the year.

"Transverse sections of the upper part of the leaf, mounted in 'Deane's gelatine,' and examined by transmitted light with a power of 225 linear, show that the fibres are not round, but roughly hexagonal, with slightly rounded angles packed closely together in bundles, but so that small interspaces are left at the rounded angles. The central canal is marked by a well-defined spot on each ultimate fibre; and around this spot are slight indications of concentric lines, showing how the cell has been built up by successive deposits of cellulose.

"The ultimate fibres vary considerably in diameter, those near the green or upper surface of the leaf being much finer than those near it's dull under-surface.

"When the ultimate fibres are broken, they break transversely, and the fracture has a ragged edge. I could not discover any tendency to tear longitudinally into finer filaments.

"The bundles of fibre are in the form of flattened bands, arranged with tolerable regularity, parallel to each other, lengthwise in the leaf, one edge of the band being close to the green or upper surface of the leaf, the other edge close to the dull or under surface. Some of the bands appear to be incomplete, and extend only to a short distance from the surfaces of the leaf.

"In the centre of each complete bundle of fibres is a brown bundle of spiral or vascular tissue; the central canals in this tissue are larger than the central canals in the fibre. This spiral tissue appears to break up very easily, and to separate readily from the woody tissue or fibre.

"The bundles of fibre are imbedded in the cellular tissue known as the parenchyma, or more accurately as the merenchyma, of the leaf, and are immediately surrounded by a layer of cylindrical cells, very similar to the cells just beneath the cuticle of the leaf.

"The cells of the cellular tissue are, for the most part, filled with the greenish fluid juices of the plant; the grains of chlorophyll—the waxy green colouring matter of the leaf—being very conspicuous in the cells near the upper surface.

"In the lower or butt ends of the leaf the ultimate fibres are much coarser, the bundles are cylindrical or oval, there is a great thickness of cellular tissue in which the bundles of fibre are imbedded, and the cells surrounding each bundle are filled with some reddish colouring matter, which, in some cases, seems to pervade the whole cellular tissue.

"The fibre appears to be quite white and colourless in every part of the leaf, until the cells in its neighbourhood are ruptured.

"From the above microscopic examination of the leaf and fibre, I have come to the conclusion that an erroneous opinion is prevalent on the following points, which are important:—

"1. There is no woody matter to be separated from the fibre; the spiral tissue cannot, I think, be considered as woody matter; and from direct examination of the so-called woody matter on imperfectly cleaned fibre, I have found it to consist of cellular tissue, and portions of the cuticle or skin of the leaf, stiffened and glued to the fibre by the dried sticky juices of the plant.

"2. The fibre cannot be indefinitely divided, the cells of the pleurenchyma or woody tissue showing no tendency to tear longitudinally into filaments.

"3. The ultimate fibres are shorter than is commonly supposed—probably not more than two inches in length, but on this point I am unable at present to speak definitely. * * * *

"The fibre consists of elongated tubular cells containing air, or perhaps a colourless liquid.

"In each bundle of fibre, very minute canals are formed by the interspaces between the separate fibres.

"The bundles of fibre are imbedded in, and surrounded by, the cellular tissue of the leaf.

"The cells of the cellular tissue are for the most part filled with sticky juices of the plant, containing chlorophyll, albumen, fibrin, pectine, starch, gluten, sugar, all that is popularly called gum, and in the butt-ends of the leaf the cells immediately surrounding the fibres contain a red fluid (probably altered chlorophyll).

"In the process of manufacture, the leaf is beaten or bruised, the cellular tissue is completely broken up, the fluid contents of the cells are set free, and, by the same cause, openings would be forced in the tubular cells of the fibre, whether those cells contained fluid or air; and if they contained fluid, some of that fluid would be pressed out.

"The result is obvious: the fluid juices would be drawn into the tubular fibres and into the minute canals between the ultimate fibres, by capillary attraction; and the tubes being so minute, the capillary attraction would act very rapidly, and with great force.

"The remedy that I would suggest is simple. It is to dilute the juices of the plant with water the very instant they are set free, so that the tubes may absorb a mixture of juice and water, the more dilute the better, instead of the pure juice.

"The following facts tend to show that the above views are to a great extent correct:—

"The fibre, as it leaves the beating or stripping machines, is green in colour, and this green colour cannot be removed by mere washing.

"When the moist fibre, washed so as no longer to tinge water green, is passed between powerful rollers, a large quantity of green fluid is expressed.

"The colour is improved by passing the moist fibre between rollers, or through a beating machine, under a stream of water, and the sooner the water is applied after the fibre has passed through the stripping machine, the greater is the improvement in the colour. For this last statement I am indebted to the manager of the Selwyn Flax Company, who has been making experiments on the washing of the fibre.

"If the beating of the green leaf is effected under water, the resulting fibre is quite white.

"If the green leaf is half dried, so that the juices may not flow freely in very minute tubes, and the fibre is then prepared by beating and subsequent washing, the fibre is much whiter than if prepared from the fresh-cut leaf in the ordinary manner, but the difficulty of separating the fibre from the cellular tissue is greatly increased.

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The results of an elaborate investigation into the intimate structure of the leaf, by Captain F. W. Hutton, F.G.S., followed the above, and was read before the Auckland Institute on the 18th October, 1869.

"* * * * * * *Development of Leaf.*—The young leaf of the *Phormium tenax*, when about a quarter of an inch in length, is composed of loose parenchymatous tissue, covered both on the inner and outer surfaces, near the centre, by an epidermis of elongated rectangular cells, the edges of the leaf being crenulated by the jutting out of the young growing cells. Imbedded in this cellular tissue lie about twenty-three vascular bundles, eleven on each side of the midrib. These, in this young state, are composed entirely of spiral vessels, which contain a single spiral fibre, easily unrolled with a needle. These bundles are 0·0013 inch broad, and about 0·004 inch apart from one another. They lie longitudinally in the leaf, towards the central part of it, the outer growing edge being composed only of cellular tissue. The upper end of each bundle runs into that lying next to it towards the centre, and they thus get shorter and shorter as they recede from the midrib. When the leaf gets about an inch long the vascular bundles are still seen to branch and anastomose with one another; but this soon ceases, and at all later stages they are very nearly parallel, converging slightly towards the point of the leaf. A layer of thin elongated tubes now makes its appearance, surrounding the bundles of spiral vessels. This is the first state of the fibres from which the plant has got its celebrity; but as yet they are exceedingly tender, and break with the slightest touch. When, however, the leaf has attained a length of four inches, the fibres in the upper part of it have acquired considerable strength, while those at the base are still quite weak. When the leaf is about nine inches long, it commences to exude gum, and appears then to be fully formed.

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† Nottidge, 1869.

"*Description of full-grown leaf.*—When fully grown, the leaf attains a length of from three to ten feet, according to soil and variety. The colour varies from light-yellow green to deep-blue green, with yellow or red margins and midribs, while the lower part of the leaf is usually pink. In shape the leaf is linear-lanceolate, and keeled, with an acute point. At a point rather less than half-way down from the tip, the two superior or inner surfaces of the two halves of the blade begin to coalesce at the midrib, and this coalescence gradually increases until one-half of the leaf is joined together. The coalescence then gradually decreases, until it occupies only about a fourth of the breadth of the half-blade, which breadth it keeps to the bottom of the leaf, the two half-blades being closely appressed as far as the base, where the two marginal edges closely overlap one another, and form a sheath through which the younger leaves grow. It is only the inner surfaces of the lower portion of the leaf, below the place where the coalescence of the two half-blades begins to decrease, that exude gum.

"For the sake of convenience, I shall, in this paper, call the upper part of the leaf the blade; that portion where the coalescence of the two half-blades reaches its maximum, and which is about half-way between the two ends ef the leaf, the butt; and the lower portion, the base of the leaf.

"The full-grown leaf is composed of parenchymatous tissue, in which fibro-vascular bundles lie imbedded, and remain isolated from one another as fibrous cords, some of which run from one end of the leaf to the other. This cellular tissue is covered, on both surfaces of the leaf, by an epidermis composed of elongated, rectangular cells, of considerable consistence, but without chlorophyll or other colouring matter.

"No stomata or other openings are found on either surface, and the gum appears to be exuded by exosmosis.

"The fibro-vascular bundles, which form what are commonly called the fibres of the plant, are composed of elongated tubular liber-cells, enclosing a centre of spiral vessels, and vary much in shape in different parts of the leaf. They are surrounded by a layer of elongated cells, that at once turn blue with iodine, and are probably cambium cells. The bundles are thickest at the base, and taper gradually to the point of the leaf.

"The spiral vessels are about 0·001 inch in diameter, and contain a single, rarely a double, spiral fibre, which can be unrolled with a needle. They are filled with air, and have no strength, but are readily broken across.

"The liber-cells on the contrary, have great strength, and form the true fibre of the leaf. They are very long, probably an inch or more,* while their thickness never exceeds 0·0006 inch, and is sometimes only 0·0003 inch. They taper each way to a more or less blunt point, each cell being distinct from the rest, and not joined together end-ways. Notwithstanding their strength, they are of very delicate structure, colourless, translucent, and almost devoid of secondary deposits, the cell-wall being from 0·0001 inch, to 0·0002 inch, thick. They are hollow, and filled only with the air, but are highly hygroscopic, imbibing water quickly, and during the operation twisting about in all directions. The fibres, although round when separated, are not so when collected into bundles, being then compressed into ovals, polygons, &c., so as to fill up the whole space, and leave no interstices. They have the same thickness in all parts of the leaf.

"At the base of the leaf the vascular bundles are scattered through the cellular tissue, in about four irregular rows. They are arranged in ovals of two sizes; the largest, whose major axis is about 0·02 inch, and minor axis 0·014 inch, enclose in their centres a rhomboidal cluster of spiral vessels; while the smaller, whose major axis is 0·015 inch, and minor axis 0·007 inch, contain none. Near the outer surface of the leaf four other irregular rows of fibre bundles, without spiral vessels, are found, whose section is lanceolate, thus making eight rows altogether in the base of the leaf. The fibres here are generally much weaker than in any other part, and can be easily torn across with a needle.

"Near the outside of the leaf the cellular tissue, in which these bundles are imbedded, is lax and translucent, but towards the interior it is open and spongy, the cells being arranged in single rows, enclosing irregular intercellular spaces, which are of a tubular form, the tubes running parallel with the vascular bundles. These intercellular passages begin to be developed when the leaf is about four inches long, and they are found only in those parts where gum is exuded. At present I have always found them empty, but it is possible that they may be gum-canals, or the glands or ducts by which gum is secreted.

"In the thick part of the butt of the leaf, the internal rows of bundles are reduced to one, the others having died out. They are here club-shaped, with a constriction in the middle, and enclose a rhomboidal bundle of spiral vessels. Besides these there is also a marginal row of bundles, the largest of which alternate with the bundles of the interior row. They are of an elongated clavate form, constricted in the middle, and with a rhomboidal bundle of spiral vessels in the thick part of the club. Between these occur three smaller bundles, of an oval form, also constricted in the middle. The central one of these, which is situated just opposite to the interior bundle, is rather more than half the length of the largest, and encloses near its inner end a rhomboidal bundle of spiral vessels. The other two are of the same form as the central one, but not much more than half its length, and the bundles of spiral vessels, which are also near the inner end, are in section like the sector of a circle, or a boy's kite. The cellular tissue which encloses these bundles is rather lax and of a light green colour, becoming close, and densely filled with chlorophyll, towards the outer side. All traces of the intercellular passages have disappeared, but in their place two cylindrical bundles of large, loose, translucent cells appear near the end of each of the smallest marginal bundles, and these continue to the point of the leaf. The cells that surround the interior bundles, and the rounded interior ends of the largest marginal bundles, are filled with a red fluid, as are also those of the midrib and margins of the leaf.

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* **Captain Hutton has since measured the length of the ultimate fibres. See p. 74.**

The vascular bundles in the free part of the leaf, at the butt are rhomboidal in section, reaching the epidermis on the outer or inferior surface, but separated by several rows of cells from the inner or superior epidermis; they enclose bundles of spiral vessels that are also rhomboidal in section. Midway between these, and near the superior surface, there sometimes occurs another small cylindrical bundle of liber-cells, without any spiral vessels, but more often this is absent. Between each of the vascular bundles there is also a cylindrical bundle of large loose cells, similar to those in the thick part of the butt. The midrib is formed by an elongated bundle of fibres, enclosing a rhomboidal bundle of spiral vessels near its inner end, and it is surrounded by three circular bundles of fibres alone.

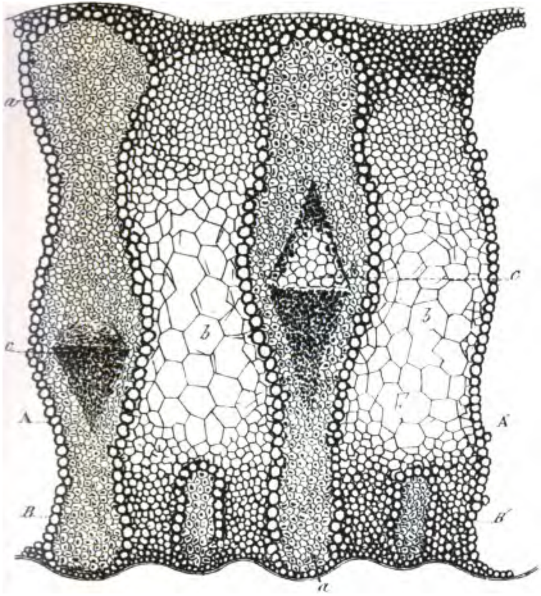
"Higher up in the blade, as the free parts of the leaf get larger, the interior bundles of the butt die out, and the medial-sized marginal bundles elongate, until they, as well as the larger ones, reach almost across the leaf from the outer to the inner surface, the smaller ones retaining their relative size. All have, however, now altered in shape; the larger ones are still clavate, but are swollen, instead of constricted,

PLATE II.

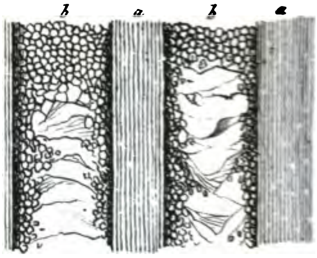
TRANSVERSE.

× 100. Linear.

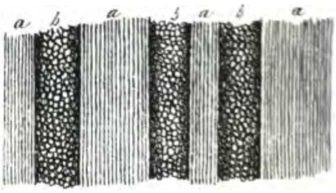
Glossy or superior surface.



Bloom or inferior surface.

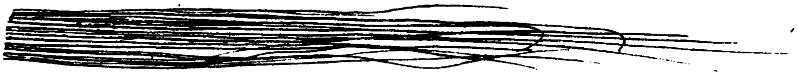


LONGITUDINAL at AA'

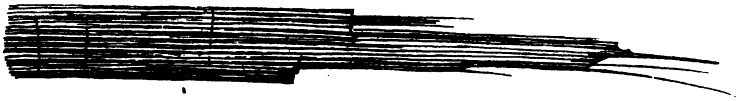


LONGITUDINAL at BB'

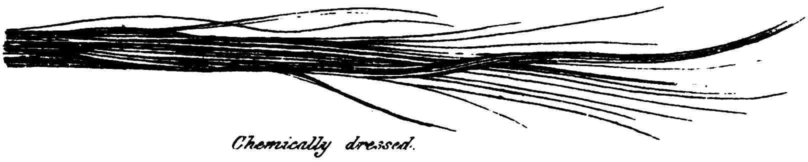
SECTIONS OF LEAF OF PHORMIUM TENAX.



Maori dressed.



Machine dressed.



Chemically dressed.

REFERENCE.

a. Fibre bundles.
b. Cellular tissue.
c. Spiral tissue.

hanna del. et lith.

in the middle; and the swollen parts contain their bundles of spiral vessels, which neither in shape nor in relative position have changed with the liber-cells. The smaller or intermediate bundles have become more clavate; but their spiral vessels have still retained their shape of the sector of a circle. Occasionally, on the inner side of the leaf small round bundles, composed altogether of fibre, are found, alternating with the bundles that cross the leaf.

"The average thickness of these bundles on the superior or inner surface of the leaf is 0·005 inch, and on the inferior or outer surface, 0·0027 inch, and their distance from one another is 0·018 inch, or fifty-five bundles to the inch. There are, therefore, about two hundred and fifty bundles of fibres in the whole breadth of the leaf, not including the intermediate bundles, which would give about as many more in the lower part of the blade near the butt; but towards the point of the leaf these intermediate bundles die out, leaving only the large ones, that go the whole way across. These also get finer and closer together the nearer they get to the point, so that there are almost as many of them close to the tip of the leaf as there are near the butt. On the inferior or outer surface, the bundles of fibres reach to the epidermis, but on the superior or inner surface, several rows of cells intervene. Each bundle of fibres is separated from the next to it, in the interior of the leaf, by a mass of lax translucent cells similar to those found in the butt of the leaf. The rest of the cellular tisse is densely filled with chlorophyll.[*] * * * * *"

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[*] Hutton, 1869.

CHAPTER XI.

Microscopical and chemical properties—(*continued*).

CAPTAIN HUTTON's views respecting the chemical constitution of the plant are more fully given in a lecture delivered before the Auckland Institute, on 12th July, 1870, from which the following is extracted:—

" *Gummy products.*—I will now pass on to the consideration of the gummy and mucilaginous products that are found in the leaf, and which are generally considered as the chief cause of all our misfortunes in endeavouring to produce a high quality of fibre. What is ordinarily spoken of as the 'gum,' is, in reality, at least three different products, viz:—1, The gum on the outside of the lower parts of the leaf.—2. The bitter principle and mucilage contained in the cells of the leaf, and which, no doubt, is a mixture of several different substances, but which I shall treat as one here.—3. The cement that binds the ultimate fibres together into bundles. And as I go on I shall show that these three substances differ essentially in their chemical properties, and must be carefully distinguished from one another when considering the best processes to be employed in preparing the fibre.

" *Gum.*—Taking first, then, the gum, which is found only on the outside of the inner surfaces of the lower parts of the leaves, we find it to be colourless or pale yellow when pure, semi-solid and viscous. It softens and swells up slightly in cold water, but does not dissolve; soaking in water for an hour or two and exposure to rain for three weeks does not affect it. It dissolves easily in boiling water, and in acids, but not in alkalies. It will not dissolve in alcohol, but neither will alcohol precipitate it from solution, although, on the addition of large quantities, it turns the solution milky white. It is precipitated by basic acetate of lead, chloride of tin, and by nitrate of mercury, but is not affected by neutral acetate of lead. These reactions show that it is unlike any gum or mucilage hitherto known, but that it has properties intermediate to both. As it occurs only on the outside of the leaves it is easily removed by mechanical means, and does not give the slightest trouble in the present method of preparing the fibre.

" *Bitter principle and mucilage.*—These are contained in the cells of the leaf, along with chlorophyll, &c. It is well known that all parts of the *Phormium* leaf have an intensely bitter taste; and when a bruised leaf or broken tissue, knocked off by the machine, is placed in water, this bitter principle is dissolved out, leaving little in the cells but chlorophyll, or the green colouring matter. The solution is brown and turbid, but when filtered is of a deep claret colour, and with a slight acid reaction. On evaporation it yields a thick reddish-brown sticky gum, of bitter taste, and readily soluble in cold water. That this solution contains little or no gum, similar to that found outside the leaf, is shown by its chemical reactions; for no change takes place on the addition of alcohol, neither does any precipitate fall when nitrate of mercury is added, but the solution is rendered turbid. On the addition of neutral acetate of lead, a large brown precipitate is formed, leaving the solution clear and almost colourless. It is also precipitated by chloride of tin, while the solution is left clear and golden yellow; and also by basic acetate of lead. No change takes place on the addition of alkalies, but acids turn it yellow and slightly turbid. It is coloured black by oxide or chloride of iron, owing perhaps to its containing some tannin. These reactions show that this mucilage is essentially different from the gum. In its original state in the cells of the plant it is colourless, but on exposure to water or moisture it rapidly turns reddish-brown, and stains the fibre; it can, however, be entirely removed by soaking the fibre in running water for three or four hours. It must not be confounded with the red colouring matter found in the butts of some leaves, for the two are quite different, as I shall point out when discussing the advantages of soaking flax. The bitter principle might perhaps be used as a dye or stain for wood, for on allowing a strong solution to stand for some days, a brown insoluble substance falls to the bottom much in the same manner as indigo; and if it should prove of any value at all, the cheap rate at which it could be prepared at or near the mills ought to secure it an extensive sale.

"*Cement.*—The ultimate fibres are held together by a cement which is quite different from either of the foregoing. It is insoluble in cold water and acids, but dissolves slowly in boiling water, and more quickly in alkalies. Pure soaked fibre, when boiled for three hours in water, yields a perfectly clear pale yellow fluid, with an acid reaction but no bitter taste, and which on evaporation leaves a brownish gummy substance, which is insoluble in alcohol or acids, but dissolves readily in alkalies or cold water. This solution undergoes no change on the addition of alcohol, or of basic acetate of lead, acetate of lead, nitrate of mercury, chloride of zinc, or perchloride of iron. On the addition of chloride of tin, a pale yellow precipitate is formed, and the solution is left perfectly clear and colourless. Alkalies darken the tint of the solution, but acids bleach it.

"It is therefore evident that this cement differs entirely from either the gum or the mucilage, but these differences will probably be made clearer to you if I bring together the effects produced by some of the re-agents.

"Alcohol has no effect on the mucilage, or the cement, but turns a solution of gum white.

"Acids dissolve the gum, and turn the mucilage yellow. They do not dissolve the cement, but bleach it.

"Alkalies have no effect on the gum or the mucilage, but dissolve the cement and turn it yellow.

"Acetate of lead has no effect on the gum or the cement, but precipitates the mucilage brown,

"Nitrate of mercury has no effect on the cement, and only renders a solution of the mucilage turbid, but precipitates the gum yellow.

"We can now understand some of the results arrived at by Dr. Hector and Mr. W. Skey (*ante*, pp. 58-60), as for instance the action of alkalies on the fibre, which they showed always weakened it very much; for although they have no effect on the gum they dissolve the cement which binds the ultimate fibres together, and so diminish their coherence; while acids, although they dissolve the gum, do not affect the cement, and therefore do not injure the strength of the fibre unless used in such quantities as to attack the ultimate fibres themselves, or the cement is dissolved by the boiling water.

"It will thus be seen that the strength of the fibrous bundles depends entirely upon the cement that holds the ultimate fibres together; and if this is dissolved, either by hot water or alkali, the whole would separate into a mass of fluff, with no coherence or strength, the fibres of which it was composed being half an inch in length.* * * * * * *"

Captain Hutton again contributed to the histiology of the *Phormium* plant by a paper "On the means of distinguishing its fibres from those of Manilla or Sisal, by the microscope," which was read before the Wellington Philosophical Society, on 26th August, 1871.

"To an experienced eye, the difference between Manilla fibre and *Phormium*, when in any quantity, is so great that I do not suppose that any mistake would occur in distinguishing between them; but when a small portion only is available for examination, as when

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* Hutton, 1870.

Manilla rope is sparingly adulterated with *Phormium*, the case is different, and unless the easily recognised marginal or mid-ribs of *Phormium* are present, the microscope will have to be resorted to before a satisfactory determination of the nature of the fibre can be made. Sisal, again, is still more difficult to distinguish by the unassisted eye from *Phormium*, than the latter is from Manilla, and I therefore propose to give the characteristics of each fibre, when examined with a microscope:—

"In *Manilla*, the fibrous bundles are oval, nearly opaque, and surrounded by a considerable quantity of dried-up cellular tissue, composed of rectangular cells. The bundles are smooth, very few partly detached ultimate fibres are seen, and no spiral tissue.

"In *Sisal*, the fibrous bundles are also oval, and surrounded with cellular tissue. They are also smooth, and very few ultimate fibres project from the bundles. They are, however, more translucent than Manilla, and can always be recognised by the large quantity of spiral fibres mixed up in the bundles.

"In *Machine-dressed Phormium* the bundles are translucent, and irregularly covered with tissue, being in places quite free from it. Spiral fibres can also be detected among the bundles, but not in the same quantity that is seen in Sisal. Many more ultimate fibres stick out from the bundles, which are flat instead of oval. In those places where the bundles are entirely freed from tissue, they are generally divided longitudinally into two or more smaller bundles, or fasciculi, and in these places the number of half-detached ultimate fibres is greatly increased; these are, however, rarely broken, most of them having the end perfect. Spiral fibres are here absent.

"In *Maori-prepared Phormium* the bundles are almost entirely free from tissue, and quite so from spiral fibres. They are always broken up into many fasciculi, which average, perhaps, some twelve or fifteen ultimate fibres in each fasciculus. Many ultimate fibres are semi-detached, and they are much more broken than in machine-prepared fibre.

"If an examination of the fibrous bundles fails to give a satisfactory result, resource must be had to the size of the ultimate fibres which compose the bundles, and this will always give a certain proof of the nature of the fibre under examination, provided enough measurements are made to strike an average, and this can always be done, as one fibrous bundle a couple of inches long will yield an ample number of ultimate fibres.

"In order to accomplish this, the fibre must be first boiled for two or three hours in a weak solution of potash, by which means it will be decomposed. It will then be found possible to isolate individual ultimate fibres from the rest of the bundle by careful dissection with needles under a microscope, the decomposed bundle being placed on a glass slide, in a drop of water. When thus prepared, it will be found that the ultimate fibres of Sisal will separate easily, those of *Phormium* with more difficulty; while it will require great care to prevent breaking those of Manilla while endeavouring to detach them. In fact, Manilla requires four or five hours boiling in a tolerably strong solution of potash, before the ultimate fibres can be detached readily.

"The following table gives the average dimensions of the different ultimate fibres, made from a considerable number of measurements of each kind:—

—	Length of ultimate Fibres, in inches.			Diameter of ultimate Fibres, in inches.			Thickness of Cell Wall in inches.
	Max.	Min.	Mean.	Max.	Min.	Mean.	
Sisal... ...	·25	·20	·21	·00140	·00098	·00112	·00028
Manilla ...	·25	·17	·21	·00098	·00060	·00083	·00024
Phormium ...	·80	·13	·39	·00070	·00035	·00045	·00015

"It will be thus seen that the average length of the ultimate fibre of *Phormium* is nearly twice that of either of the others, while the average diameter is not much more than half that of Manilla, which again is much less than Sisal. The cell wall also of *Phormium* is also much thinner than that of either of the other two."*

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* Hutton, 1871.

CHAPTER XII.

Microscopical and chemical properties—(*continued*).

THE evidence adduced by Captain Hutton in the foregoing chapter, did not, however, meet with universal acceptance, and was criticised in a paper, read before the Wellington Philosophical Society, on 17th September, 1870, by Mr. William Skey, Analyst to the Geological Survey Department.

In this communication the author first points out that the gum from the *Phormium* leaf is precipitated from its aqueous solution by alcohol, and that it therefore is to be classed with all other gums and mucilages in that respect. Nor do his experiments confirm the chemical distinctions that Captain Hutton has described between the outer gum of the leaf and the mucilaginous substance in the cellular tissue. Respecting the proof adduced of a cement as a separate principle in the economy of the plant, the assumed function of which is to bind together the ultimate fibres, Mr. Skey states, "to me, these ultimate fibres seem quite free and clear of each other upon their longitudinal surfaces, if only they are taken fresh from the plant and kept moist. However, the determination of this microscopically I leave for others, and I proceed to discuss the supposed chemical identification of this cement. Captain Hutton affirms that 'the pure soaked fibre, when boiled for three hours in water, yields a pale yellow fluid, with an acid reaction, but no bitter taste, which on evaporation leaves a brownish gummy substance, insoluble in alcohol or acids, but readily soluble in alkalies and cold water.' Now, I obtained an extract having the same chemical properties from Swedish filter paper (which is always held to be pure cellulose), by giving it full contact with boiling water for three hours, and this was after well washing the paper first in cold water, so that anything adherent to it accidentally, which could in any way affect the result, would be removed; all the water used having been freshly distilled.

"Simultaneously with the colouring of the water, bubbles of carbonic acid gas were evolved from the filter paper; and the same results were observed in the case of the purest *Phormium* fibre when thus treated, while its surfaces acquired a distinct brown colour.

"The fact then appears that the prolonged contact of boiling water with vegetable fibres effects chemical changes upon them, whereby they become more or less coloured, and yield portions of extractive matter to the water employed. It follows, therefore, that the substance extracted by Captain Hutton from the 'pure soaked fibre' is not necessarily a cement at all, but might be, and no doubt is, in part or wholly, a product of the metamorphosis of the pure fibre itself. Granting, however, for the moment, that nothing but a cement has been removed in these experiments, I do not clearly see that the reactions, stated to have followed from the addition of the various chemical agents to the solution obtained, establish anything at all in relation to the nature of such cement.

"The effect of prolonged contact with hot water, by Captain Hutton's own experiments, exercises such a radical change upon the supposed cement, that it no longer refuses to dissolve in cold water, and has acquired besides a deep brown colour. Clearly, therefore, the reactions cited as belonging to, and characteristic of, the supposed cement, properly refer to some body or bodies chemically distinct.

"Taking all this into due consideration, I am compelled to think that as yet Captain Hutton has neither demonstrated the presence of cement in the *Phormium* plant performing the duty he ascribes to it, nor yet, supposing such a cement to exist, that he has informed us anything more of its properties than that it is insoluble in cold water and acids."*

At a meeting of the Wellington Philosophical Society, on 26th August, 1871, Mr. Skey gave the following notes:—"On the presence in certain fibres of a substance susceptible of some striking colorific changes, when chemically treated."

"In attempting to bleach some samples of *Phormium tenax* with chlorine, I experienced such difficulty that I was led to investigate into the cause, when certain re-actions manifested themselves, which I think proper to communicate at once, as they show that there exists in certain fibres a substance which, as far as I can learn, has not yet been described in chemical works, and from the deportment of which with certain re-agents, we are able easily to discriminate those fibres which contain it from those in which it is not present.

"The results arrived at up to the present time are as follows:—

"1. That a number of fibres (that of the *Phormium tenax* included), when allowed contact with chlorine, hypochlorous, or chromic acid, acquire a pale yellow colour, which is changed to a beautiful rose red when the fibres are afterwards treated with alkalies, alkaline carbonates, or earthy carbonates; while acids restore the yellow tint when applied to the reddened fibres.

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* Skey, 1870.

"2. That the alkaline manganates affect these fibres in the same manner as chlorine, etc., except that they are blackened by a deposit of oxide of manganese, which, when removed by the proper acids, leaves the fibre of a yellow colour, subject to the same colouration by contact with alkalies as in the above experiment (No. 1).

"3. That these fibres are coloured a pale yellow by alkalies and their carbonates, but, in the case of these last, the colour is paler than with the alkalies.

"4. That by cold, strong, nitric acid they are coloured red-brown, which changes to a yellow tint on contact with alkalies.

"5. That slightly diluted cold sulphuric acid renders these fibres quite yellow; while the concentrated acid blackens them at common temperatures.

"6. That when treated for a long period with chlorine, hot chromic, or nitric acids, these fibres are completely whitened, but deteriorated in strength. The addition of ammonia or sulphuric acid has then no colouring effect on them.

"7. That *Phormium tenax* exhibits the same reactions with these several re-agents, and in as great a degree when previously digested for two hours in boiling ether, alcohol, or chloroform, or for eighteen hours in boiling water, or when soaked in cold water for eight days.

"8. That *Phormium tenax* fibre cut up into lengths of one-eighth of an inch and digested for twelve hours in boiling water exhibits as well marked reactions to chlorine in conjunction with ammonia, or to sulphuric acid, as it did before such treatment.

"In the annexed columns, the effects of ammonia on the oxidised fibres of certain plants in relation to these changes of colour are stated:—

Coloured Rose Pink.	Coloured Brown.	Unaltered.
Phormium tenax ...	Wood ...	Hemp.
Yucca	Manilla, impure ...	Sunn Hemp.
Sisal	„ pure (?)...	Rheea.
Aloe		Raw Cotton.
		Linum.

"A great number of samples of *Phormium tenax* have been experimented with, the results being always similar; among these have been:—

"1. Those prepared by machinery only.

"2. Those prepared by a short retting process and machined afterwards.

"3. Those prepared by Maoris—the cleanest I could obtain.

"4. Some prepared by myself and which had never been dry, and some of them which had been steeped in water five days.

"In respect to the flax (*Linum*) used, it had no appearance of being bleached but only retted, but I am anxious to learn whether the fresh fibre of this plant would behave to these tests the same as that of the *Phormium tenax*.

"This, together with a great many other points, will require time to determine. It would be desirable, for instance, to know if long continued retting would remove or change the principle on which the colouration of the fibre depends, and also the effect of sunlight; also, whether the principle is as abundant in the fibre at one season of the year, as at another, and if it is equally dispersed through the several varieties and parts of the leaf.

"It is premature as yet to enter fully upon the deductions which these results would lead to, but I think the following points are clearly established:—

"1. That certain fibres, among which is *Phormium tenax*, contain a substance quite distinct from the fibre, though such fibres have been prepared with the greatest care and appear to be quite pure.

"2. That this substance is insoluble in hot or cold water, also in alcohol, ether, and chloroform, and in aqueous solution of hydrochloric acid.

"3. That a small portion of it is on the outside of the fibre, as shown by the carbonate of lime test.

"4. That the whole of this substance is probably in chemical combination with the fibre.

"5. That it cannot be removed chemically without injuring the fibre, as even pure fibre *(cellulose)*, which does not contain this principle, is weakened considerably when passed through these processes.

"In reference to the nature of this principle it is difficult to conjecture, as it clings so persistently to the fibre as to appear inseparable, except in an altered state.

"From the blackening of the fibres containing it by sulphuric acid

I infer that it is non-nitrogenous—probably it is allied to some of the colouring principles of madder.

"When oxidized by chlorine, &c., it has the colour of fresh turmeric paper, which paper is, like this, reddened by contact with alkalies.

"In conclusion, I may observe that this substance is not unlikely to be the basis of the yellow and red colour of the *Phormium tenax* and other plants, and that while it may not be necessary to remove it from these fibres for many purposes to which they may be applied, it is questionable whether we can have them of a pure unalterable white colour, without its removal.

"*Further Notes.*—1. The fresh fibre digested for twenty-four hours in a weak solution of caustic potash, is whitened in those portions of it which have freest access to the liquid, that is the ends and outside portions, and such portions do not then give any reaction with ammonia after contact with oxidizing agents.

"2. That prolonged contact with cold hypochlorous acid also renders such parts colourless, or nearly so, and that ammonia has then no effect upon such fibres.

"3. That, by stopping the second process when the fibre is thus divested of the principle giving the reactions before described, such fibre does not appear to be greatly weakened, whether it is tested dry or wet.

"4. That, in the case of the first experiment, the fibre is more weakened than in the second; but, still, not so much that the fibre appears very easily or readily detached into ultimate ones.

"Taking all these results into consideration, I do not see that they tend as a whole to establish any theory which may be brought forward, that regards the principle thus indicated as a cement.

"It is certainly a very definite principle, but the functions it may, or does, perform in the growing plant we have yet to learn.

"I may state that I have not found it with certainty away from the fibres, while it seems a constant associate of them in their natural, or, at least, in their green state."*

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* Skey, 1871.

CHAPTER XIII.

Microscopical and chemical properties—(*continued*).

With the view of arriving at a definite opinion on the important questions raised in the valuable papers quoted above, the following further researches were made, at the instance of the Commissioners, in the Government Laboratory:—

"*Action of Fresh Water.*—The nature of the matters extracted from different kinds of fibre by boiling water was made the subject of further experiment, and especially to ascertain their behaviour with the different re-agents suggested by Captain Hutton (*ante*, page 72) for the purpose of distinguishing the 'cement.' The fibres examined were—

"1. Fibre extracted from the green leaf of the *Phormium*, variety *Manunu*, in the Laboratory, by simple scraping and washing in cold water, care being taken never to allow it to become dry, until all tissue and juice of the plant was removed.

"2. Maori-dressed fibre, from the young leaf.

"3. Maori-dressed fibre, from the old leaf. Both these were from the fine variety known as *Rataroa.*

"4. Machine-dressed fibre, prepared from the young leaf by Messrs. Logan & Sinclair.

"5. Sisal hemp.

"6. Manilla.

"In each case the samples, before being experimented on, were washed continuously, till they ceased to impart any extractive matter to cold water. In making the extract the same conditions were preserved in every case, as to the amount of water, temperature, and degree of concentration of the solution obtained.

"The results obtained have been placed in the appended table.

"1. The specific gravity of the solution indicates the proportional quantity of matter extracted from each fibre by boiling. This, it appears, is least in the *Phormium* fibre, which had been prepared without ever being allowed to become dry, and greatest in machine-dressed fibre. The fibre dressed by the Natives, the Sisal hemp, and the Manilla, all yield the same proportion, and considerably more than the well-cleaned *Phormium* fibre. The amount of extractive matter contained in the fibre that is not easily soluble in cold water, but is so in hot water, has therefore an evident relation to the care with which the fibre has been cleaned. At the same time, in the case of sample No. 1, which is a perfectly white, or rather colourless, fibre, the process of boiling effected the same change of colour as was observed when filter paper was operated on, which tends to show that the fibre, or some portion of it, undergoes a change.

"2. The character of the extractive matter obtained from these fibres appears to be in each case the same; the different behaviour with re-agents employed being only such as are due to the different strength of the solutions. It was thus found, when proper precautions are taken to secure a pure solution of the supposed cement, that it proves to have properties identical with the solution obtained from fibre in which the juices of the plant have been allowed to dry. Also, that the extractive matter is to some extent at least due to an actual change of the fibre itself, probably oxidation; and lastly, that the description of the reactions by which it has been proposed to distinguish this supposed cement as a definite element in the structure of the plant, is in some fundamental points incorrect.

"Experiments were also made in another form to determine the effect on the fibre of the removal of the extractive matter. A given weight of fibre was dried at 212° Fah., and was found to lose 14·88 per cent. of its weight. A similar sample was first boiled for four hours in water and then dried, and was found to have then lost 16·66 per cent., or about 2 per cent. of dry extractive matter had been removed by the boiling.

"The strength of the samples was then carefully ascertained to be as follows:—

"1. Broken in ordinary state	85
"2. Dried at 212°	75
"3. Boiled and broken wet	80
"4. Boiled and dried at 212°	71

"*Action of Fresh and Salt Water on Rope.*—In a report dated 12th August, 1870, the result was given of experiments made in the Laboratory with ropes made of Manilla and *Phormium* fibres, relative to the alteration in length and weight which they underwent during successive wettings and dryings.

"1. It was found in every case that both fresh and salt water extracted a quantity of greenish black matter from the New Zealand rope, but that nothing was extracted from the Manilla.

COMPARISON of the REACTIONS of the EXTRACTS of various FIBRES.

Name of Specimen.	Specific Gravity of Extract.	Colour of Extract.	Re-actions with undermentioned Re-agents.				
			Basic Acetate of Lead.	Acetate of Lead.	Nitrate of Mercury.	Chloride of Tin.	Degree of Coloration of Fibre.
1. Flax prepared in Laboratory	1000·6	Very pale yellow.	Very slight precipitate.	Slight precipitate.	Moderate precipitate, not so heavy as 1, 2, 3, 4.	Very slight precipitate.	Very slight.
2. Flax, Maori-dressed, first pair of leaves.	1001·6	Pale brown ...	Moderate do.	Moderate do.	Heavy precipitate.	Slight do.	Slight.
3. Flax, Maori-dressed, third pair of leaves.	1001·7	Deep brown ...	do. do.	Heavy do.	do. do.	do. do.	Greater than 2.
4. Flax, machine-dressed, Logan and Sinclair, young leaf.	1003·0	Brownish yellow.	do. do.	Heavy do.	do. do.	do. do.	A little darkened.
5. Flax, machine-dressed, Logan and Sinclair, old leaf	1002·7	Brown ...	do. do.	Heavy do.	do. do.	do. do.	Notably darkened.
6. Sisal	1001·8	Pale yellow ...	do. do. less than 2, 3, 4, 5.	Slight do.	do. do. but not so much as in 2, 3, 4, 5.	Very slight do.	Slight.
7. Manilla	1001·5	Pale brown ...	Moderate precipitate.	Moderate do.	Heavy precipitate.	do. do.	Much darkened

"2. The New Zealand is much harder and stiffer when wet than the Manilla, and looser in texture when dry.

"3. The Manilla shows less difference in length when wet and dry than the New Zealand, especially after treatment with sea water.

"The difference between the two kinds of rope is, however, on the whole very slight, as disclosed by these tests, and only tends to prove that the New Zealand rope is more prone to absorb moisture and undergo other changes, indicating that the fibres of the plant still retain more of the properties of fresh vegetable tissue than in the case of the Manilla.

Size of rope.	Normal length.	Normal weight when dry.	Length after 12 hours soaking in fresh water.	Length after drying at 212° F.	Weight after drying.	Length after 12 hours in sea water.	Length after drying at 212° Fahrenheit.	Weight after drying.	Strain required to gain the normal length.
									lb.
2½	12	100·30	11·50	11·55	96.76	11·22	11·55	94·80	60
2½	12	106·65	11·37	11·50	98·0	10·8	11·1	100·52	122*
2¼	12	99·20	11·50	11·67	95·15	11·2	11·6	94·47	100
2	12	84·70	11·47	11·75	83·1	11·52	11·6	81·33	60
1½	12	56·80	11·39	11·55	55·95	11·2	11·6	53·75	50
1½	12	42·83	11·62	12·1	39·1	11·45	11·55	39·00	12*
1¼	12	45·25	11·52	11·67	44·5	11·3	11·7	42·50	40
1	12	33·96	11·44	11·56	32·9	11·58	11·8	32·83	45
1	12	23·55	11·55	12·2	21·55	11·2	11·45	21·83	20*
½	12	19·57	11·23	11·35	17.45	11·26	11·77	17·06	20
½	12	9·50	11·00	11·9	8·55	11·3	11·85	8·75	20*

* Manilla. The rest *Phormium.*

"*Effect of Boiling Sea Water on the Fresh Leaf.*—The effect of boiling the *Phormium* leaf in sea water was also made the subject of experiment, and it was found that when the leaf is first bruised and then immersed in boiling sea water for three hours, the fibres are set free, and a large quantity of extractive matter is removed without their strength being impaired. Fresh water in which *Phormium* is boiled becomes acid, but the sea water in these experiments remained neutral.

"*Effect of Sea Water on the Prepared Fibre.*—In continuation of the foregoing experiments, and especially with the view of testing the nature of the matter which in machine-dressed *Phormium* tends to bind the fibre into flexible woody bundles, the following experiments were made.

"A small portion of the following fibres were thoroughly washed, cleaned, and finely divided, and then soaked in sea water for fourteen hours. The character of the extract was noted, and the change in the appearance and strength of the fibre when dried was also ascertained.

"Samples of the same fibres were also boiled for two hours in sea water, and the same observations were made.

"1. Fibre extracted from the green leaf in the Laboratory, and thoroughly washed free from all extractive matter. This fibre was nearly pure white, and though it divided freely into its ultimate fibres, still possessed a degree of strength (93) in excess of ordinary samples. This fibre, having a mere trace of extractive matter, was unaltered in appearance after treatment with cold and hot sea water, and its strength was also unimpaired.

"2. Fibre prepared by the Natives, soft, lustrous, and freely divided. This sample differed from the former in having been allowed to dry after the removal from the leaf before the extractive matters had been washed out. It coloured both hot and cold sea water pale brown, and was itself slightly changed in colour, whilst its strength was reduced 20 per cent.

"3. Machine-dressed. This was a sample that had been steeped after passing through the stripper, and was clear, bright, and of a good colour. It was affected to the same degree by both the hot and cold sea water, but not so much as the Maori-dressed sample, and its strength was only reduced 10 per cent.

"4. Manilla. This fibre imparted a pale brown colour to the cold sea water, and a dark brown to the hot, its strength being unaffected.

"5. Sisal hemp gave the same results as Manilla.

"These experiments prove that the action of sea water on all these fibres is in proportion to the amount of extractive matter which they contain, and that it has no specific action on the pure fibre.

"*Action of Alkalies on the Fibre.*—Portions of different kinds of *Phormium* fibre, and also of Manilla hemp, were submitted to the action of a strong solution of caustic potash, and kept at the boiling point for four hours.

"The result was in every case the same, as has been described by Captain Hutton, the fibre being reduced to a soft pulp, like the 'half stuff' of paper manufacturers, in which the ultimate fibres are perfectly non-coherent so long as the mass remains wet, but when dried possessing a considerable amount of tenacity. This is rendered very obvious by the behaviour of an untwisted thread of the fibre thus prepared, which will bear a strain of several pounds when dry, but immediately on any portion of it being touched with a drop of water, will not bear as many grains.

"This experiment was varied in several ways, care being taken to remove the last trace of the alkali from the fibre by treatment with dilute acid and subsequent washing, which had the effect of making the fibre extremely soft, silky, and white, but without in the least depriving it of the above singular property. Alcohol, ether, oil, and other non-hydrating fluids were substituted for the water, but were found not to reduce the cohesion of the ultimate fibres. When examined under the microscope in the dry state the prepared fibre is found to consist of shrivelled and collapsed ultimate fibres, twisted and matted together; but, on the addition of water, they are easily observed to become distended and separated from one another, acquiring, at the same time, a well-defined smooth outline. The form of the ultimate fibre itself is not much affected, nor does it appear to be in any degree weakened by the action of the potash, as broken cells are rarely seen, even when the dry fibre is parted with some violence; while in the wet state, the ultimate fibres can be separated for examination with great facility.

"The action of the alkali, therefore, appears to be that of altering, and probably thinning the cell wall, so as to render it capable of absorbing water with rapidity. The fact that the *Phormium* fibre can be reduced by a single process to the 'half stuff' of the paper maker, but having the very unusual property of being composed of complete fibre cells, having an equal length of about half-an-inch, and at the same time possessing a pure colour and glossy lustre, may perhaps lead to the introduction of a totally new class of manufacture, by which a material will be obtained with even greater facility than ordinary paper of fine quality, and at the same time possessing an even texture, cohesive strength, and 'body.'

"After the proper form is given to the fibre, by taking advantage of its gelatinous condition when wet, there would be no difficulty in drying it in contact with such a material as would prevent the fibres again absorbing water.

"*Action of Acids.*—When a mineral acid was substituted for the alkaline solutions, in experiments similar to the preceding, the fibre exhibited a totally different result; becoming feeble, harsh, and under the microscope showing that the fibre cells were weakened, as, whether broken wet or dry, the ultimate fibres themselves invariably snapped across and presented broken ends. The effect of the application of chlorine, as in the ordinary bleaching process, was the same as that of the acids, but to a less degree."*

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* Commissioners, 1871.

SPECIAL REPORTS.

SPECIAL REPORTS MADE TO THE COMMISSIONERS, 1871.

Instructions to reporters.

THE special reports which follow, on the microscopical and chemical structure of the *Phormium tenax*, were obtained in accordance with a resolution of the House of Representatives of 10th September, 1870.

The investigations were undertaken by Dr. W. R. McNab, and Mr. A. H. Church, F.C.S., Professors of Botany and Chemistry respectively, in the Royal Agricultural College at Cirencester, and did not reach New Zealand until 16th October, 1871, after the publication of all the foregoing information, so that the conclusions arrived at in the Colony were quite independent of anything stated by these gentlemen.

The points submitted by the Commissioners to the Reporters for investigation were as follows:—

"1. Comparative microscopic analysis of the structure of different parts of the fresh leaf:—*a.* butt; *b.* blade; *c.* tip; *d.* glossy surface; *e.* bloom surface; in each case showing the relative proportions and arrangement of the various tissues in the various parts.

"2. Prepared fibres—microscopic comparison of the varieties of *Phormium* fibre, Manilla hemp, Irish flax, Russian flax—showing relative form and dimensions of the ultimate fibre, and the mode in which they are in contact laterally.

"3. Chemical analysis of the proximate constituents of the different parts of the *Phormium* leaf, for the purpose of determining the chemical reaction of the different gummy and extractive matters, and the relative proportion in which these exist in the butt and blade of the leaves. A most desirable point to determine chemically is whether any change analogous to ripening takes place in the juice of the leaf which would indicate the best period for cutting it.

"4. The tables of the relative strength of fibres given in books being defective, it is desirable that a series of experiments should be undertaken to determine the breaking strain of all the different kinds of fibre in the market, tested both as straight fibre and when twisted into strands.

"5. The investigation of the peculiar action of sea water on rope made of ***Phormium*** fibre, and the reason for its not absorbing tar, as has been alleged, will naturally form part of the third branch of the subject already indicated."*

In forwarding the statement of the results of their experiments the Reporters stated that "neither the time given to it, nor the other conditions of the inquiry, had enabled them to treat the subject exhaustively. On this account the tables of breaking strain could not be undertaken, as this investigation would have necessitated the use of elaborate and expensive machinery."

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* Commissioners, 1871.

REPORT ON THE MICROSCOPIC STRUCTURE OF PHORMIUM TENAX.

BY

PROFESSOR W. R. McNAB, M.D.

§ 1. GENERAL CONCLUSIONS.—From the results of the microscopical studies which I have made of the *Phormium tenax*, I conclude—

1. That the best fibres are those which have the smallest cavity, and the greatest thickness of wall.

2. That the fibres at different parts of the leaf are of very different values. As the leaf developes from above downwards, the fibres at the apex will be much older than those at the base. Microscopical examination also shows that the fibres at the base (lower part of the butt) and apex (last inch or two of the leaf) ought to be rejected. The leaves themselves ought also to be very carefully selected.

3. That the fibres situated near the under surface of the leaf are often inferior in quality, and that the microscopic structure of the leaf shows that these bundles can only be separated from the tissues with the greatest difficulty.

4. That no cement exists binding the cells together; the so-called cement of Captain Hutton (see p. 71) being the primary cell wall, consisting of cellulose, and easily soluble in chlorate of potash and nitric acid.

5. That the gum existing on the epidermis of the upper surface is not likely to damage the fibres in any way, and can be easily got rid of along with the epidermis.

6. That the differences, chemical and microscopical, between *Phormium* and Russian hemp, and Irish flax, render it improbable that the *Phormium* can ever be profitably applied to the same uses.

7. That the resemblances, chemical and microscopical, between *Phormium* and Manilla hemp, show that *Phormium* ought to furnish valuable material for the manufacture of ropes, &c. For this end I would urge that the fibro-vascular bundles be extracted from the leaf as nearly entire as possible, and with care, taking advantage of the cellular sheath surrounding them; this ought to be practicable, but the fibres close to the inferior epidermis ought not to be removed.

8. That as the Natives have overcome all the difficulties, a process as simple as possible ought to be employed, and while the bundles are not broken up into their ultimate cells, every care ought to be taken to preserve the natural oily and fatty matters in the fibre.

§ 2. STRUCTURE OF THE BUTT OF THE FRESH LEAF.—*A. Lower portion.*—The butt, or lower portion of the leaf, may be more accurately described as the *sheath*. Microscopically it presents two very different kinds of structure, the basal portion having the tissues arranged in a very different manner from those at the upper portion of the butt or sheath of the leaf.

The basal portion of the butt is generally of a reddish brown colour, and contains a peculiar coloured substance in many of the cells. Besides this colouring matter, very large crystals of *calcium oxalate* were also observed. On section the basal portion exhibits (with a power of about 50 diameters) an upper and a lower epidermis, with a quantity of cellular tissue, while scattered up and down in the cellular tissue the fibro-vascular bundles are seen. The upper superior, or inner epidermis, is composed of minute cells, the outer or free wall not being greatly thickened. Beneath is the cellular tissue of the leaf, the cells of which for a short distance are small and densely packed together. More towards the central portion of the leaf, the cells show well marked intercellular spaces (air spaces or lacunæ) which give a peculiar appearance to the section. The cells are more or less regularly arranged in bead-like rows, the spaces or lacunæ between these rows. The intercellular spaces are not equally well marked at every part of the section, in many places the tissue being dense. Towards the inferior lower, or outer epidermis of the leaf the tissue becomes dense, the cells not presenting evident intercellular spaces. Below the epidermis the cells are small and densely packed together, while the epidermis consists of small cells, with the free surface greatly thickened, and forming a well marked cuticle.

The fibro-vascular bundles are scattered in the cellular tissue between the upper and lower epidermis. These fibro-vascular bundles present two very well marked varieties. Those near the inner or superior epidermis are complete, and made up of numerous tissues, while those near the lower or inferior epidermis are composed exclusively of the *elongated prosenchymatous wood-cells*, which form the fibres of the *Phormium*. The intermediate bundles sometimes show a kind of transition from the one form to the other, a small inner portion of the bundle being left unchanged into wood-cells.

The different forms of cells making up the fibro-vascular bundle from the inner side of the leaf, can be easily made out by examination with a higher power (250 diameters). Numerous large openings can be observed in the middle of the bundle, which are the spiral and pitted vessels cut across. On each side of the large openings very small cells are to be seen, the cambiform cells of the bundle; while the thickened prosenchymatous cells are well developed on the outer or lower side—those on the inner side being only slightly developed. The cells are large, and the walls thin and only slightly thickened.

One of the intermediate bundles shows that the large openings, spiral vessels, &c., are wanting, that the portion of pro-cambium left is very small, the outer prosenchymatous cells being well developed, and forming about 18-20ths of the whole bundle, while the inner prosenchymatous cells are only slightly developed, being represented by only about five or six cells. In the bundles near the outer or inferior epidermis all the pro-cambium has been converted into prosenchymatous cells, each bundle being thus quite homogeneous in structure; no trace of spiral or other vessels being observable. The most characteristic feature of the bundles from the outer or inferior side of the leaf is the large size of the cavity of the cell. The walls are thin, and the size of the cavity shows that the fibres will have comparatively little strength; and also, that owing to the thinness of the walls of the ultimate cells, it will be very difficult to separate them one from the other. The prosenchymatous cells from the bundles on the inner or superior side of the leaf are very different in appearance. The cavity of the cell is very small, and the thickness of the cell-wall great. These cells are, however, few in number when compared with the others. The best kind of fibre is therefore very deficient in the lower portion of the butt, while the inferior fibres are abundant.

The parenchymatous cells at the base of the leaf contain more or less protoplasm and nuclei; but no chlorophyll was observed in the cells.

The epidermis of the upper or inner surface of the leaf has only a very slightly developed cuticle, while the epidermis of the lower or outer surface is made up of cells of small size, much thickened on the free surface, and covered with a very thick cuticular layer.

In the lower part of the butt of the leaf the cellular tissue largely predominates, forming about 3-5ths or 4-5ths of the whole. The fibro-vascular bundles vary very much in character, some consisting entirely of the prosenchymatous cells, others containing only a few. The large size of the cavity of the prosenchymatous cells shows that they will possess but very little strength; and also, that there will be very great difficulty in separating these ultimate cells on account of the thinness of the wall.

The fibres from the lower part of the butt cannot be considered to be of good quality, and probably it will be found best in preparing the fibre for manufacturing purposes to reject entirely that contained in the lower part of the butt of the leaf.

B. The Upper portion of the Butt.—Here the arrangement of the tissues corresponds for the most part with that at the lower portion of the butt.

The superior or inner epidermis is composed of small cells, with only a very slightly developed cuticular layer. In many specimens no cuticle is visible, the cuticularized outer wall of the epidermal cells being also thin. Higher up in the leaf the cuticle is thick and well developed. It is at this portion of the leaf that the *Phormium* gum is mostly developed. At first it is a viscid semi-fluid substance, which speedily dries into thin laminæ. This gum is apparently not produced by glands or secreting organs in the tissues of the leaf, but is a superficial formation, produced by degenerative changes occurring in the thick cell-wall and cuticular layer of the epidermis of the upper or inner side of the sheathing portion of the leaf. This accounts for the absence of a thickened cuticle on that part of the leaf, and also for the absence of all glands or openings on the surface of the leaf by which the gum can be secreted. Gum *tragacanth* is formed in a somewhat similar manner by degeneration of cell-walls; and in sea-weeds, the so-called 'intercellular substance' is produced in a similar way. In the spores of *Pilularia* and *Marsilia* a gummy secretion is formed at the expense of the cuticular layer. Very little chlorophyll exists in the cells below the upper epidermis at this part of the leaf.

The cellular tissue of the leaf resembles greatly that of the lower butt, but now the fibro-vascular bundles are seen to be more regularly arranged, and the air cavities or intercellular spaces are much more marked.

The fibro-vascular bundles, near the inner or superior surface, are complete with prosenchymatous wood-cells, spiral vessels, and cambiform cells, the prosenchymatous cells being well developed on both sides of the bundle. Close to the inferior, or outer epidermis, the bundles are not constituted in the same way, in them the prosenchymatous wood-cells largely predominate, and in a few, spiral vessels exist, while in others only wood-cells are visible. These bundles are very regularly arranged, close to the lower epidermis, and only separated from it by two or three small cells. Between these bundles the cells containing chlorophyll are placed, and give a very characteristic appearance to the section.

The large intercellular spaces form a very marked feature in the transverse section of the leaf. They are regularly arranged in a single row in the middle of the leaf, and separate more or less accurately the bundles of the upper side of the leaf from the bundles of the lower. The lower epidermis consists of a layer of small cells, with a well marked cuticular layer. This arrangement holds both for the thick portion of the sheath, and the thin lateral parts.

The quantity of fibre in this part of the leaf is greater than that in the lower portion of the butt. Near the lower epidermis the bundles are placed very close together, and form about half of the tissues, while in the rest of the leaf the bundles are few and scattered, and not occupying more than 1-10th of the tissue.

At this portion of the leaf small intercellular cavities, containing a dark reddish-brown fluid, were observed; one situated on each side of the middle line of the sheath, on the superior surface. Similarly coloured marks were also observed on the leaf, but as their development could not be traced by means of the specimens examined, no opinion can be given respecting them. The irregular arrangement of the cells surrounding them, and their varying depth from the surface is to be noticed. In some places the gum on the surface was deeply coloured of the same tint as the colouring matter contained in these cavities. Careful examination of the development of the leaf would be the only way to make out the true nature of these structures, and to do that would not come within the sphere of a preliminary report like the present.

§ 3. STRUCTURE OF THE BLADE AND TIP OF THE FRESH LEAF.—*A. Lower Portion.*—As the lower portion of the leaf, or butt, could be more correctly described as the sheath, so the whole upper portion may be described as the blade or lamina. As we described the lower and upper portion of the butt, or sheath, so we may describe the upper and lower portion of the lamina, the tip or apex, and the blade.

Above the butt, or sheath, the blade appears as a well marked flattened expansion, with a strongly marked keel on the lower side, this keel extending down the butt. No gum is now formed by the upper epidermis, which is glossy and dark green. The margin of the keel and the edge of the leaf is reddish-brown in colour, and differs from the other parts of the leaf in appearance.

The arrangement of the different tissues in the leaf differs considerably from that in the sheathing portion. We do not find the fibro-vascular bundles arranged in the same way. The complete bundles, near the inner or superior surface, have disappeared, and we have these bundles placed so as to be in relation to both sides of the leaf, and stretching right across the mesophyll. The small bundles are arranged so as to be close to the inferior epidermis, while a few incomplete bundles are placed close to the upper epidermis. The intercellular spaces, or lacunæ, are largely developed, and divide the large complete bundles one from the other. Cells containing chlorophyll are found on both sides of the leaf, more or less surrounding the intercellular spaces, and placed between the fibro-vascular bundles. These transparent spaces also change in character. Instead of being evident lacunæ they are now composed of numerous cells of large size, with very thin walls, and probably able to carry air in the same manner as the intercellular canals. Another well marked difference in the structure of the leaf is observable, namely, that all the fibro-vascular bundles are partly surrounded by a cellular sheath; a single row of cells, which sharply defines them from the surrounding tissues. This sheath is only very slightly developed in the upper part of the butt, and is altogether wanting in the lower part of the butt. The sheath is, however, not complete, as it is wanting on the side of the bundle next the lower epidermis. Here, as in the other parts of the leaf, the fibro-vascular bundles approach very near the epidermis, and are not separated by many cells. It may also be considered as wanting on the other side ef the bundles, but the numerous large cells below the epidermis, on the superior side of the leaf, may be looked upon as completing it.

The keel and coloured edge of the leaf is covered by a very thick cuticular layer, this being coloured gives the peculiar appearance to it.

The bundles near the edge become small, and are complete, each bundle being separated from the other by lacunæ. Near the centre (middle line of the leaf) small bundles are developed between the large ones, but at all parts the same relative position in regard to the upper and lower epidermis is preserved.

B. Upper portion of Blade or Tip of the Leaf.—In the upper part of the leaf the same relations of parts is preserved as in the lower portion of the blade. The bundles, however, diminish very considerably in size, and the quantity of spiral vessels and cambiform cells increases, while the prosenchymatous cells diminish. The bundles, when seen in transverse section, run across the mesophyll, and are placed between the intercellular spaces, several cells separating the bundle from the upper epidermis, while the lower epidermis is in close contact with the bundle. They are also provided with the cellular sheath, like the bundles lower down. The thick coloured cuticle on the keel and margins of the leaf is, in all respects, the same as that described on the blade. The fibro-vascular bundles are best developed on the upper or inner side, few prosenchymatous cells existing on the under side. If the leaf was therefore split at this part, the best fibre would be found on the upper part, and only a small quantity on the under side. Lower down in the leaf this arrangement does not hold, there being as much fibre on one side as on the other; while in some cases more fibres actually exist on the under than on the upper side. The epidermis cuticle cells, containing chlorophyll, &c., resemble those of the other parts of the leaf, and already described.

Large fibro-vascular bundles exist close to the keel and edge of the leaf. These contain much prosenchyma, but are not surrounded by a sheath of cells like the other bundles in the leaf.

§ 4. GLOSSY OR SUPERIOR SURFACE.—The glossy or superior surface is covered with a well developed epidermis. The cells are narrow, and not greatly elongated. A very thick cuticle exists on the free, or outer surface. This cuticle is best developed on the blade, while on the sheath it is very thin when the gum has been formed. The thickened cuticle seems to furnish the material out of which the gum is formed. No stomata exist in the epidermis of the upper side of the leaf.

"§ 5. BLOOM OR INFERIOR SURFACE.—The epidermal cells on the bloom or inferior surface of the leaf are small, but more elongated than those on the upper surface; the elongation being in the direction of the long axis of the leaf. A well marked alternation of structure of the lower epidermis is seen, an alternation of a band with stomata, and a band without stomata. The band without stomata is found over the prosenchymatous bundles; while the band with stomata exists only over the cells containing chlorophyll. This gives the peculiar banded appearance to the lower surface. The stomata are well developed, and are quadrangular, resembling very much the stomata of the Agave.

They are very closely packed on the portion of the epidermis on which they exist, while none are to be met with on the epidermis covering the prosenchymatous fibres.

§ 6. MICROSCOPICAL CHARACTER OF PREPARED FIBRES OF PHORMIUM TENAX.—The fibres of *Phormium tenax,* which are used for manufacturing purposes, consist of the *prosenchymatous wood-cells,* which form part of the fibro-vascular bundles existing in the plant. In this way the *Phormium* is perfectly distinct in its anatomical and physiological character from Irish flax and Russian hemp. In the plant the prosenchymatous wood-cells exist in bundles, composed entirely of these cells, but much more frequently mixed up with a number of other cells or vessels. The bundles are thus of a very different value, some containing much valuable fibre, while others contain comparatively little. When examined with the microscope, the ultimate prosenchymatous wood-cells appear as elongated, more or less cylindrical fibres, tapering towards each end, the tapering ends of the cells over-lapping. The length of these cells is very difficult to determine, and all attempts to isolate a single perfect cell have as yet failed. They must, however, be of considerable length, as several cells have been traced for 2½ inches. The cell, when isolated an viewed from the side, appears as a transparent cylinder, with a cavity. The relative sizes of the cell and of the cavity vary very much, and measurements of many fibres are given in this Report. The measurements were obtained by using the *Camera lucida,* and are expressed in fractions of an English inch. The microscope was fixed so that when a power of 500 diameters was used, 1-1000 of an inch in a stage micrometer was magnified to half an inch. Each fibre was carefully drawn, and by means of an ivory rule and compasses the size of both the fibre and cavity could be ascertained with the greatest accuracy. In transverse section the cells appear more or less polygonal, and possess well marked pores or pits on the wall. These pits are very small, and not very numerous,—the pit on one cell always corresponding with another on the next cell. The wood-cells making up the fibres of *Phormium* are thus porous or pitted cells. The pits are best seen in thin transverse sections of the fibro-vascular bundle, and require a power of 500 diameters for their demonstration.

In structure and general appearance the fibres of *Phormium* resemble those of Manilla hemp, while they entirely differ from those of Irish flax and Russian hemp. Both Russian hemp and Irish flax consist of *Bast-fibres,* the fibre both of Manilla hemp and *Phormium* being the prosenchymatous *wood-cells* of the fibro-vascular bundles. While these fibres thus differ anatomically and physiologically, they also differ chemically.

If we take six test-tubes, and place in each a portion of one of the fibres, say, carded cotton in No. 1, Irish flax in No. 2, Russian hemp in No. 3, Manilla hemp in No. 4, *Phormium* in No. 5, and a portion of pine wood in No. 6, then pour a little fuming nitric acid on each, on washing the fibres carefully with water and dilute ammonia we obtain very characteristic results.

No change is produced in the appearance of the carded cotton, the colour and general appearance remaining the same, but by microscopical examination it is found that the fibres have lost their peculiar twist to a considerable extent, and become more cylindrical.

Irish flax—The *Bast-fibres* remained unaltered in colour and general appearance, but under the microscope it was seen that the fibre was very distinctly marked with longitudinal striæ, and the cavity in each fibre was well marked. Here and there portions of wood adhered to the fibres, and these became deep brown in colour.

Russian hemp remained also unchanged in appearance, the fibres showing well marked longitudinal striæ under the microscope. Portions of wood adhering to the fibres became coloured deep brown.

Manilla hemp became at once deeply coloured by the nitric acid, and this colour remained after washing with water and ammonia. When allowed to remain in water for some time, it coloured the water yellowish brown. The bundles of fibres were stained, but were little altered in appearance—single fibres, however, becoming more or less twisted.

Phormium, when treated with nitric acid like the others, became deep brown, like the Manilla hemp, and when allowed to remain in water tinged it yellowish brown. The sample used had most of the ultimate fibres separate, and the action of the nitric acid was well marked, the fibres becoming twisted and contorted in a very peculiar way.

The pine wood treated with nitric acid gave results similar to those obtained by treating Manilla hemp and *Phormium*, the wood becoming deep brown, and tinging the water in which it was placed of a yellowish brown hue. The wood-cells were also twisted very slightly.

We must therefore conclude that *Phormium* is much more closely related to Manilla hemp than to Irish flax or Russian hemp; and in this way we need not devote much time to comparing the fibres, either as regards their structure or relations.

A. Native Samples.—No. 1* of samples of prepared *Phormium* may be taken as a good sample. In it the fibres, or wood-cells, are united in bundles, but are separable without much difficulty. When examined with the microscope it is found that the cells have a very considerable diameter, varying from ·0006 to ·0008, and that the cavity is small, having only a mean diameter of ·00015. In this sample a single bundle was observed in which the cells were from ·0007 to ·0009 in diameter, the cavity having a mean breadth of ·0004. The ultimate cells were very difficult to separate one from the other, and the bundle appeared dull and wanting in lustre to the naked eye.

The characteristic then of a good native sample of prepared *Phormium* is the small size of the cavity compared with the diameter of the fibre. All the strength of the fibre will depend on this, and also it is evident that the thick-walled cells can be much more easily detached one from the other than fibres with thin walls.

No 3† of the samples examined consists of the fibre from the underside of the leaf, which is rejected by the Natives. The fibres vary much in character. Some of the bundles contain very few prosenchymatous wood-cells, and consist chiefly of spiral and porous vessels. Then again, the epidermis adheres closely to the fibro-vascular bundles, and cannot be easily separated, while the cells containing chlorophyll are abundant. In this sample we not only have the bundles dirty from adherent tissue and matter inside the cavity of the fibre, but the bundles are both deficient in prosenchymatous cells, and these, when present, are of inferior quality. They are much more irregular in size, varying from ·00035 to ·0008, while the cavity varies in diameter from ·0001 to ·00035. The size of the cavity shows that the fibre is much weaker, and also that the ultimate cells will be much more difficult to separate one from the other, the thin wall not having strength to withstand the force necessary to separate the bundle into its ultimate cells. If we take the mean measurements of a number of cells of samples Nos. 1 and 2‡ we find that the mean diameter of seventeen fibres is ·000655, while the mean diameter of the cavity is ·000154. Taking the diameter of the cavity as 1, the mean diameter of the cavity would be to the diameter of the fibre as 1 to 4·25. If we take No. 3 sample, the mean diameter of eighteen fibres is ·000582, while the mean diameter of the cavity is ·000191, the mean diameter of the cavity being to the diameter of the fibre as 1 to 3·04; the fibres being on the average smaller, while the cavity is larger. Eighty-eight fibres from the Native samples were measured and gave a mean diameter of ·000603, and mean diameter of the cavity ·000187, or in the proportion of 1 to 3·22.

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* *Harakeke.*—Common swamp flax from Otaki; stripped and scraped with a shell, then washed for a few minutes in running water. Selected leaves of twelve or eighteen months old.

† From the same plants as Nos. 1 and 2, but stripped from the bloom (or outer) side of the leaf. The tissue obstinately adheres to and discolours these fibres

‡ Same as No. 1, but not washed.

B. Machine-dressed Samples.—In the machine-dressed samples the bundles of fibres had to be more or less broken up, and in this way the samples were irregular, sometimes many of the ultimate fibres being separated, at other times the fibres being closely united in bundles. The characteristic of the machine-dressed sample is the great variation in diameter of the fibres, varying as they do from ·00035 to ·001, while the diameter of the cavity varies from ·000075 to ·000625. In these samples it was very evident that much of the fibre was of inferior quality, that the cavity was so large, and the wall so thin, that the ultimate cells could not be separated, and all attempts to separate them would result in the production of a large amount of waste. Taking the mean of seventy-six fibres from the machine-dressed samples, we get ·000534 as the mean diameter of the fibre, and ·000151 as the mean diameter of the cavity, the cavity thus being to the fibre as 1 to 3·53.

Taking the mean of all the fibres measured (164 in number) we get ·000569 as the mean diameter of the fibre, and ·000169 as the mean diameter of the cavity, or as 1 to 3·36.

§ 7. MICROSCOPICAL CHARACTER OF PREPARED FIBRES OF MANILLA HEMP.—Manilla hemp occurs in coarse threads of varying size, which are the fibro-vascular bundles of the plant, removed apparently without any attempt being made to break up the bundles into their ultimate cells or fibres. In appearance the ultimate cells or fibres of Manilla hemp closely resemble those of *Phormium tenax*. They are cylindrical, with a large cavity in the centre. The fibre has, in general, a greater diameter than that of *Phormium*, but the cavity is always much larger. The following measurements show this:—

	Diameter of Fibre.	Diameter of Cavity.
A	·00065	·00025
B	·0007	·00035
C	·0008	·00045
D.	·00125	·0009

They are very variable in size and breadth of cavity, resembling very much a bad sample of *Phormium* fibre. The bundles can only with difficulty be separated into their ultimate fibres or cells, and when doing so for microscopical examination the fibre was nearly always injured, the cavity being easily destroyed.

The Manilla hemp consists of *prosenchymatous wood-cells*, and is, anatomically and physiologically, the same as the fibres of *Phormium*.

A good deal of cellular tissue adheres to the bundles of fibres, but it is colourless, and there is no trace of epidermis or cells containing chlorophyll, as in the case of *Phormium* fibres.

§ 8. MICROSCOPICAL CHARACTER OF PREPARED FIBRES OF IRISH FLAX.—The ultimate bast-fibres of which this flax is composed are not united in large bundles, a few fibres only adhering, and in the specimens examined many of the fibres were quite free one from the other. The fibres appear as a greatly elongated cylinder, with a cavity sometimes well marked, sometimes scarcely visible, at other times wanting. Adhering to the fibres, and often more or less discolouring them, were fragments of tissue, sometimes the epidermis with stomata, from the stem; at other times the cells of the soft bast- or wood-cells from the central portion of the stem. The diameter of the fibre varies from about ·0004 to ·0006.

§ 9. MICROSCOPICAL CHARACTER OF PREPARED FIBRES OF RUSSIAN HEMP.—Russian hemp differs entirely in appearance from Manilla hemp and *Phormium*, but resembles Irish flax very much in its general character. The fibres are more or less separate, some entirely free others in small bundles. The fibres vary very much in diameter, some being very broad, others narrow, and they appear like longitudinally striated cylinders. Sometimes a cavity exists, at other times none can be traced. The fibres are, on an average, from ·0005 to ·0007 in diameter, and in one fibre in which the diameter was ·0007 the diameter of the cavity was ·0001.

Some cellular tissue was observed adhering to the fibres, but they were cleaner than the fibres of Irish flax. Like Irish flax the hemp consists of bast-fibres, and is, anatomically and physiologically, different from the fibres both of Manilla hemp and *Phormium*.

§ 10. NATURE OF THE SO-CALLED CEMENT.—The walls of all tissue-cells are constructed on the same type. We have first the primary cell-wall, a thin plate or lamella, composed of cellulose. In thickened cells the thickening material appears as a deposit on each side of the middle lamella, and in general this secondary wall has a different composition from that of the primary cell-wall or middle lamella. In the *Phormium* the primary cell-wall consists of cellulose, which is coloured blue by a solution of iodo-chloride of zinc (Busk's solution), while the secondary wall, making up the great mass of the cell, consists of ligneous matter, and is coloured yellow with Busk's solution. If, therefore, a thin section of the bundle of *Phormium* fibres be treated with Busk's solution, the so-called cement is shown to consist of cellulose, and is coloured blue, while the great mass of the fibre is stained yellow. The cellulose, which forms the primary cell-wall, is that which is soluble in chlorate of potash and nitric acid (Schultz's process). All the different fibres, Manilla hemp, Russian hemp, and Irish flax, are united in the same way. As this primary cell-wall has small triangular spaces at the places where neighbouring cells meet, and always shows a tendency to split (as in the ripening of fruits in which the cells separate one from the other by splitting of primary cell-wall), little difficulty will exist in separating the fibres one from the other if the walls are strong and thick enough to bear it. The thick-walled fibres used by the Natives, and in which the fibres are separable, demonstrate this fact clearly. As the cells of the *Phormium* differ in no way from all other tissue-cells in the way in which they are united, it is hardly necessary to say more on this point.

REPORT ON THE CHEMISTRY OF PHORMIUM TENAX.

BY

PROFESSOR A. H. CHURCH, M.A., F.C S.

§ 1. General Conclusions.—From the results of the chemical studies which I have made of the *Phormium tenax*, I conclude—

1. That the best and strongest prepared *Phormium* fibres are those which, while fulfilling the requisite physical conditions and the microscopic conditions determined by Dr. McNab, contain the smallest quantity of mineral matter and the largest quantity of hygroscopic water.

2. That the age or stage of development of the fibre has much to do with its chemical deportment, and with its strength; and that a considerable portion of the fibre in the leaf must be condemned, both on microscopical and chemical grounds, as of very small value.

3. That *Phormium* fibres are more easily and more considerably affected by chemical reagents and by water at the boiling point, and at higher temperatures, than most other fibres used for fabrics, ropes, &c.

4. That *Phormium* fibres are very readily wetted by water and by sea-water, and that this wetting takes place to a small extent even after the fibres have absorbed a considerable amount of wood tar. The microscopic structure of the fibre serves to explain this observation.

5. That the fact stated in (4) above, taken in connection with the observation that *Phormium* fibres contain much matter soluble in water or liable to change, helps to account for the decay of ropes made with this material.

6. That the use of a mixture of lubricating, or machinery paraffine oil with wood tar seems to prevent the entrance of sea-water and the proneness to change in *Phormium* fibre. It is also suggested that as the conversion of *Phormium* fibres into *papyrine*, by a brief immersion in sulphuric acid, of the strength used in the manufacture of vegetable parchment seems to toughen, strengthen, and waterproof them, this process might be made use of to improve inferior samples of fibre.

7. That the ultimate fibres are not held together by any cement, but by their cell-walls. These, however, being easily affected by various agencies, are, together with other changeable constituents of the material, a cause of disintegration and weakness.

8. That the treatment of the plant of *Phormium*, or of its fibre with alkaline matters, especially at a high temperature, may by removing the oil, tend to cause the harshness shown by some fibres, and otherwise injure them.

9. That the use of the softest water, of a well regulated temperature, and of effective yet uniformly exerted mechanical power, seems to be of importance in the preparation of *Phormium* fibre.

The relative value of different processes of treatment and bleaching did not come within the scope of the present preliminary inquiry, but could be ascertained with much greater ease than before, through the data given in the present report.

§ 2. ANALYSES OF FIBRE OF PHORMIUM TENAX.—Summary of four series of experiments to determine the amount of moisture or hygroscopic water, and of ash or mineral matter, in certain samples of prepared *Phormium* and other vegetable fibres for comparison.

Phormium tenax.	Per centage in various fibres of	
Native dressed—	Water.	Ash.
No. 1. *Harakeke*, selected 12 to 18 months old, stripped, scraped, and washed ...	12·76	·50
No. 2. The same, but not washed ...	11·87	·93
No. 3. From same plants as 1 and 2, but from the opposite side of leaf ...	11·15	1·50
No. 5. Common swamp flax from Otaki, stripped, but not washed or scraped...	10·77	1·61
No. 6. Same as No. 5, but hand hackled...	11·05	1·23
No. 7. From the Waikato	11·52	·73
Machine dressed—		
No. 8. Mr. Stonyer, Kaiapoi	12·49	·44
No. 9. Captain F. W. Hutton, Waikato ...	11·31	·59
No. 10. T. S. Macffarlane, Auckland ...	11·81	·53
No. 11. G. Booth, Waikoura Mills ...	11·81	1·09
No. 12. Rikys' process	11·91	·71
No. 13. M'Farlane & Wilson, Whakatane	11·61	·63
No. 14. John Journeaux, Wellington ...	10·77	1·08

Other fibres—	Per centage in various fibres of Water.	Ash.
Manilla Hemp	13·22	2·02
Russian Hemp	10·47	1·44
Irish Flax	10·76	1·23
Carded Cotton	7·23	·11
Swedish Filtering Paper	8·85	·46

§ 3. CELLULOSE IN PHORMIUM FIBRE.—The term "cellulose" is used in chemical and botanical literature without much precision. The whole question of the real nature of the substances named "cellulose," "bast," and "fibre," requires a thorough investigation. In the following experiments I have aimed at comparative rather than absolute results; but, at the same time, I have not rested content with indications furnished by the usual method of determining the per centage of fibre in vegetable products. A control of the results has been attempted by means of the employment of three different processes. As these methods will be frequently alluded to subsequently it may be as well to describe them briefly here.

I. *The Nitric Acid and Potassium Chlorate process, or F. Schultze's process.*—Two grams* of the dry substance are placed in a glass stoppered bottle with 1·6 gram potassium chlorate, and 24 grains nitric acid of spec. grav. 1·10. The mixture is left for fourteen days at a temperature not exceeding 18° Centigrade. At the expiration of this time, the contents of the bottle are mixed with some water, brought upon a filter and washed, firstly with cold and secondly with hot water. When this washing is complete, the fibre is emptied into a heater and heated to 74° C for about 45 minutes with weak ammonia solution (1 volume commercial ammonia to 50 volumes of water). The fibre is then brought upon a weighed filter; and washed, firstly with dilute ammonia, as long as this passes off coloured, then with cold and hot water, then with alcohol, and lastly with ether. Carded cotton gave by this method 91·15 per cent. of residue. Carded cotton may be regarded as one of our purest forms of normal cellulose, as may be seen by the following analysis:—

Hygroscopic water	7.56
Cellulose	91·15
Oil	·51
Ash	·11
Albuminoids and undetermined ...	·67
	100·00

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* The gramme of 15·432 grains is here meant, and also throughout the Report.

II. *The Acid and Alkali method.*—Three grams of the powdered or finely cut sample are placed in a large beaker, 150 cubic centrimeters of water added, and the mixture brought to the boiling point, with constant stirring to avoid burning, 50 centrimeters of five per cent. $H^2 SO^4$ are then added, and the boiling continued for half an hour; the normal total volume of 200 cubic centrimeters being maintained throughout the operation by the addition of a little boiling water. Collect on a filter the residue from the digestion with acid, after having syphoned off the clear supernatant liquid. The residue is to be thoroughly washed on the filter with hot water, and then syringed off the paper into the beaker with about 100 cubic centrimeters of hot water. Fifty cubic centrimeters of a five per cent. solution of Na HO are next added and the beaker filled up with hot water to the mark indicating 200 cubic centrimeters. The mixture is boiled for half an hour, some cold water added, and the whole allowed to rest. When the supernatant liquid is clear it is syphoned off, and the residue collected on a weighed filter, washed with the dilute ammonia water used in method I. as above; and in the remaining steps of the process treated exactly as described in detailing that method.

III. *The Sulphuric Acid method.*—One gram of the substance is placed in a small stoppered bottle with 30 cubic centrimeters of sulphuric acid of specific gravity 1·53, and allowed to rest 36 hours. The mixture is then washed into a beaker, diluted with water, filtered, and the residue on the filter washed with warm water. The rest of the process is conducted as in methods I. and II. This method removes from mixed fibres all the normal cellulose they contain, dissolving, for instance, *cotton* completely, and *linen* nearly so, but removing smaller quantities of substance from wood tissue.

CELLULOSE.—Determinations of the per centage of Cellulose in various specimens of prepared *Phormium tenax* fibre, and in other fibres, for comparison.

	By Method I. per cent.	By Method II. per cent.	By Method III. per cent.
Phormium fibre No. 1.	73·1	...	...
„ „ No. 5.	67·5	...	...
„ „ No. 9.	69.0	...	...
„ „ No. 11.	72·0	49·76	7·1
Manilla Hemp	68·80	...	...
Irish Flax	74·10	...	...
Russian Hemp	72·10	...	...

At a slightly higher temperature Method No. I. gave rather smaller per centage of residual cellulose. In these cases, which are given below, the residues were treated successively by Methods II. and III., and thus the cellulose, and incrusting or deposited matters, were separated into three kinds:—

	Method I. Per cent.	Method II. Per cent.	Method III. Per cent.
Phormium fibre No. 1.	64.25	52.22	·48
„ „ No.13.	63·00	46·45	·70

It will here be seen that the cellulose and fibre were divisible into three parts, by a succesive treatment by Schultze's process, (I); by the acid and alkali process, (II); and by the sulphuric acid process, (III). The results may be thus rendered:—

Per cent.

Phormium fibre, No. 1.—

Crude Cellulose=64·25

Made up of	12·03	insoluble by I., soluble by II.
	51·74	insoluble by II., soluble by III.
	·48	insoluble by I., II. and III.

Phormium fibre, No. 13.—

Crude Cellulose=63·00

Made up of	16·55	insoluble by I., soluble by II.
	45·75	insoluble by II., soluble by III.
	·70	insoluble by I., II., and III.

§ 4. ACTION OF WATER AT VARIOUS TEMPERATURES UPON THE FIBRE OF PHORMIUM TENAX, &c.—I. Clean flax fibre (linen), in the form of Swedish filtering paper, was first tried. Boiled with distilled water for twelve hours it gave up to the water about one per cent. of organic matter, and about three quarters per cent. of mineral matters chiefly silica. The numbers were as follows:—

	Grams.
Swedish filter, employed weight	·55
Weight of dry substance extracted ...	·0095
Of which the Ash amounted to	·0040
And the organic matter dissolved ...	·0055

The water did not become acid in this experiment.

II. A similar filter to that used in experiment I, was digested with water in a sealed tube at a temperature fifty degrees above boiling water, namely, at 150° Centigrade. The digestion was continued four hours. The water became of a straw yellow colour, but remained neutral to test paper.

	Gram.
Swedish filter employed	·55
Weight of red-brown extract dissolved by water	·016
Weight of ash in this residue	·0055
And the organic matter dissolved ...	·0105

III. When ·5 gram of *Phormium* fibre (No. 1) was boiled twelve hours with distilled water, the liquid remained neutral to test paper; on evaporating to a small bulk the residual solution did show a faint acid reaction. The dry matter in this solution corresponded to 3·6 per cent. of the fibre taken.

IV. When ·5 gram of *Phormium* fibre (No. 2) was digested with distilled water, in a sealed tube, at 150° C. for four hours, the water became turbid and of a distinct acid reaction, with smell of burnt sugar. On washing the fibre with water a pink colouring matter was developed. The amount of substance removed from the fibre at 150° C. by water amounted to 19 per cent. of the original weight taken. It was a brown soluble substance, which gave a ready precipitate of red copper sub-oxide when boiled with Fehling's test for sugar. This result may have been due, however, to the presence, not of any kind of sugar, but of "pyrocatechin," or some allied product. The solution was sweet, with a bitter aftertaste.

V. Manilla hemp, similarly treated, gave similar products, amounting to 15·4 per cent.

VI. Irish flax, similarly treated, gave similar products, amounting to 10·4 per cent.

VII. St. Petersburg hemp, similarly treated, gave similar products, amounting to 10·0 per cent.

From the foregoing results it will be seen that prepared and cleansed *Phormium* fibre is acted upon by boiling water to more than three times the extent to which flax from *Linum usitatissimum* is affected by the same treatment. And at the higher temperature, from one-fifth to one-fourth of the whole *Phormium* fibre is dissolved by water, while the true flax fibre does not lose more than two per cent. of its weight under the same circumstances.

These facts point to an inherent difference in the quality of the organic substances, making up the material of the *Linum* and *Phormium* fibres.

Manilla hemp was similarly affected, as in the case of *Phormium* fibre, 15·4 per cent. of organic matter being removed from it by water, at 150 ° C.

Under the same circumstances, Irish flax lost 10·4 per cent. of organic matter, and Russian hemp 10 per cent.

§ 5. NITROGENOUS MATTERS, OR "ALBUMINOIDS" IN THE PREPARED FIBRE OF PHORMIUM TENAX.—It was found by a careful analysis of No. 11 specimen of *Phormium* that it contains ·267 per cent of nitrogen. This corresponds to a per centage of albuminoids, amounting to 1·69 per cent.

In the perfectly dry flax (No. 11), the amount of nitrogen is ·301 per cent., and the amount of albuminoids is 1·91 per cent.

This proportion is greater than that found in many other prepared fibres. Careful analyses of cotton (carded) and linen (Sweedish filter paper) gave the following results, which are here put down by the side of those just recorded:—

———	*Phormium.*	Cotton.	Linen.
Per centage of Nitrogen ...	·267	·079	·087
Per centage of Albuminoids	1·69	·50	·55

§ 6. OIL OR FAT IN THE PREPARED FIBRE OF PHORMIUM TENAX.—The presence of an oily matter of some sort in the cleansed and prepared fibres employed in the manufacture of textile fabrics is not generally recognised. This oily matter, as it occurs in the dressed fibre of *Phormium tenax* and in Manilla hemp, is, in great part, volatile at the temperature of boiling water.

With the sample of *Phormium* fibre, No. 10, the following results were obtained:—

Per centage of oil, dried at 100 ° C. (212 ° Fahr.) ... ·25
" " " " " "in vacuo" 1·08

In Manilla hemp—

Per centage of oil, dried at 100 ° C. ... ... ·11
" " " " " "in vacuo" ·48

In carded cotton—

Per centage of oil fixed at 100 ° C. ... ... ·51

Vegetable fibres of all kinds, from which the natural oil has been removed by heat, alkalies, or solvents, are harsh and dry to the touch, and easily and rapidly wetted by water.

§ 7. ABSORPTION OF SEA WATER BY PHORMIUM FIBRE.—In the experiments made on this subject it seemed that the *Phormium* fibres were more quickly and thoroughly wetted by sea water than were those of Manilla. More action on the fibres also occurred in the case of the *Phormium*. The extent of the absorption was measured by immersing the soaked fibres in a solution of nitrate of silver, and then exposing them to sunlight.

It may be mentioned, in this connection, that *Phormium* fibres, which had been carefully dressed with Stockholm tar, were still capable of taking up a small quantity of sea water.

§ 8. ABSORPTION OF WOOD-TAR BY PHORMIUM FIBRE.—No difficulty whatever was found in causing prepared fibres of *Phormium* to take up as much tar as those of Manilla. When a small quantity of paraffine, machinery, or lubricating oil was mixed with the tar, several advantages seemed to accrue. This oil, which is the last product of the distillation of petroleum, &c., imparts flexibility to the fibre, gives it greater tenacity, and, by its remarkable diffusive power, serves to keep out sea-water and other aqueous liquids. Being itself unalterable and unoxidizable, this oil has no tendency to promote chemical changes in the fibre which has been dressed with it. As, however, it does not dry, it cannot be used alone.

§ 9. The foregoing analyses enable me to present a tolerably complete idea of the constituents which go to make up 100 parts of one of the samples (No. 13) of dressed *Phormium* fibre.

Analysis—

Water	11·61
Ash	·63
Cellulose, A.	16·55
Cellulose, B.	45·75
Cellulose, C.	·70
Oil, partly volatile	1·08
Albuminoids	1·69
Gum and matters, soluble in water at 150° C.	21·99
	100·00

The oil and albuminoids in the above analysis are transferred from the analysis of similar fibres, Nos. 10 and 11 respectively.

§ 10.—ANALYSIS OF THE FRESH PLANT OF PHORMIUM TENAX.—The plant operated upon was received from the Royal Gardens at Kew, in May. One half of two leaves (65 and 68 inches in length respectively) was operated upon, being carefully cut up, mixed and sampled for the experiments now to be related.

The plant analysed contained:—71·95 per cent. of water.
28·05 „ dry matter.

100·00

This dry matter contained in 100 parts—

Fixed oil and fat (soluble in ether) ...	2·55
Resin and chlorophyll (soluble in alcohol)	3·24
Gum and matters (soluble in cold water)	17·29
Starch and matters (soluble in hot water)	4·28
Albuminoids	5·05
Ash, or mineral matters	5·56
Cellulose and fibre, by process I. (See § 3)	44·47
Other substances not specially determined	17·56
	100·00

These results are not given as by any means complete, though it is hoped that they will serve to indicate the proper direction for further inquiry into the best treatment for the preparation of the fibre from the plant. To this point another series of experiments tended; in these the nature of the 44·47 per cent. of cellulose, above given, was tested. It was found that it lost 8·71 parts by treatment with acid and alkali in process II., leaving 35·76 per cent. This residue treated by process III, left a final residue amounting to 11.37 per cent. of the dry plant. Comparing this result with that obtained in the similar treatment of the prepared fibre (see § 9) it is clear that much hard and corky substance in the original plant is rejected in the processes of manufacture.

The analysis of the *fresh* plant will be represented by the following numbers:

	Per cent.
Water	71·95
Fixed oil or fat	·72
Resin and chlorophyll	·91
Gum and matters (soluble in cold water)	4·97
Starch and matters (soluble in hot water)	1·20
Albuminoids	1·51
Ash or mineral matters	1·59
Cellulose and fibre, by method I. ...	12·47
Undetermined	4·68
	100·00

In considering the nature and proportion of the various ingredients of the *Phormium* leaf enumerated above it must not be forgotten that nearly all of them are present, to some extent, in the best prepared fibre derived from this plant. This matter has been already discussed in §§ 2 to 6, and in § 9.

APPENDIX.

APPENDIX.

APPENDIX I.

LIST OF NAMES OF THE VARIETIES OF PHORMIUM TENAX DISTINGUISHED BY THE NATIVES.*

Name.	District and Authority.	Remarks.
Aonga	Bishop Selwyn	A variegated flax.
	East Coast, Heaphy	*Awanga* (?)
Arotara	Waikanae, Native	Poor fibre; yellowish green leaves; dark brown edge.
Ate	Hauraki, Bishop Selwyn	*Haro;* requiring to be scraped by a shell.
	Wanganui, Woon	Strong fibre; used for eel nets and baskets.
Atewhiki	Taranaki, Kelly	Fibre very white; used for best garments; leaf narrow; reddish tinge; edge and keel narrow; bright scarlet line.
	Ditto Hursthouse	First-rate quality.
	Opunake, Native	Breaking strain, 77.†
Atiraukawa	East Coast, Heaphy	*Hatiraukawa?* Used for finest mats, probably same as *Oue*.
	Taranaki, Kelly	Best and most abundant fibre, not large, but a quick grower; leaf bronze when mature, light olive green when young, rather pointed; edge dull dark brown, lighter in inner margin, sometimes brown, relieved by a bright red line.
	Ngatiruanui, Woon	Lengthy and strong fibre.
	Opunake, Native	Breaking strain, maximum 90.
	Christchurch Domain, Armstrong	Leaf broad, light green, abrupt at the points, edges light brown.
Harakeke	Mantell	Also, *Haraheke.*
	Waikanae, Native	Common swamp flax.
	Otaki, Native	Name for all flax, except *Wharariki.*
	Waikato, Hutton	Strip of leaf ⅛in. broad, broke at 42lbs.

* Commissioners, 1871. † Relative to Manilla=100.

Name.	District and Authority.	Remarks.
Hewara	Opunake, Native	Breaking strain, 77.
	Waikanae, Native	Broad, buff green leaf, with dark narrow edge.
Huhiroa	Mantell	Or *Uhiroa* (?)
	West Coast, Heaphy	Yields best fibre, probably *Oueroa.*
	Wanganui, Woon	Long fibre; used for fine and *porae* mats, fishing lines, nets, ropes, &c.
	Taranaki, Kelly	Good fibre, easily separated from gum; leaf blueish green; narrow edge black or very dark brown; keel reddish chocolate; leaf gradually narrows to a point.
	Opunake, Native	Breaking strain, 98.
	Christchurch Domain, Armstrong	Leaf very long, tapering at the point; edges light brown.
Huruhuruhika	Taranaki, Kelly	Used for rough garments; bears a general resemblance to *Takaiapu.*
	Opunake, Native	Breaking strain, 87.
Karuamoa	Waikanae, Native	Good fibre; tapering leaf; dark chocolate edge.
Kauhangaroa	Hawke's Bay, Nairn	Used only for baskets and matting; easily breaks with a jerk.
	Ditto Native	Good white fibre, soft, and silky.
	Government Domain, Christchurch, Armstrong	Two variegated forms; per centage of fibre 19·6; leaves large coarse edges, and base dark brown.
Kohunga	Maungatautari, Bishop Selwyn	*Tihore.*
	Ditto Mantell	Fine kind.
Korako	Taranaki, Kelly	Used for best garments; dark green leaf; edge, a narrow line of dark brown; keel, a pale yellow.
	Ditto Hursthouse	First-rate quality.
Koura	Wanganui, Buller	Best fibre for *Korowai*, or shaggy mats.
Kuroa	Christchurch Domain, Armstrong	Per centage of fibre, 17·8.
Kuru	Opunake, Native	Breaking strain, 95.
Manunu	Taranaki, Kelly	Used for rough purposes.
	Opunake, Native	Breaking strain, 90.
	West Coast, Heaphy	Or *Manunui* (?); good for cordage.
	Ditto Mantell	Best variety.
Matoroa	Pipiriki, Woon	Strong and durable; short fibre, used for borders of fine mats.
Motu-o-rui	East Coast, Heaphy	Also, *Awanga*—a variegated kind; fibre unserviceable for manufacture.
Ngaro	Taranaki, Kelly	Used for rough garments.
	Waikato, Jenkins	Good fibre; blueish green leaf; black edge.
	Raglan, Snackenburg	Best of all the kinds, for all purposes.
	West Coast, Heaphy	Stiff fibre.
Ngarowaka	Waikato, Jenkins	Good fibre for mill purposes; leaf bright green, red edge.
	Waiuku, Constable	Cultivated; soft, fine fibre.
Ngatotomawe	Opunake, Native	Breaking strain, 84
Ngutunui	Taranaki, Kelly	For best garments; quick grower; leaf similar to *Takaiapu*, but has a blunt point, and is red at the butts.

Name.	District and Authority.	Remarks.
	Opunake, Native ...	Breaking strain, 95.
	Waikanae, Wi Tako Ngatutu	Much esteemed leaf; dark olive green, with dark red edge.
	West Coast, Heaphy ...	
Ngutuparera ...	Taranaki, Kelly ...	For rough garments.
	Opunake, Native ...	*Parera* (?) ; breaking strain, 95.
	West Coast, Heaphy ...	Or *Ngutuparura* (?)
Oka Oka ...	Waiuku, Constable ...	One of the best varieties; cultivated.
Oue ...	Christchurch Domain, Armstrong	Leaf narrow, very strong, edges orange coloured; per centage of fibre 34·1.
	Taranaki, Kelly ...	Leaf narrow, of an olive green; edge and keel orange coloured; used for best garments.
	Hawke's Bay, Locke ...	Fine fibre, next to *Tapoto.*
	Whakatane, Native ...	Best variety, white and soft; breaking strain, 91.
	Waikato, Hutton ...	Typical *Tihore.*
	Ditto Mantell ...	A fine fibre; also, *Ouhe.*
	East Coast, Heaphy ...	Also, *Tapoto,* cultivated at Coromandel, Kawhia, and Waikato; glossy leaves, rather red at the edge; has a general orange-green appearance at a distance.
	Maungatautari, Bishop Selwyn	*Tihore.*
Paheke ...	Opunake, Native ...	Breaking strain, 87.
Parekoritawa	Taranaki, Kelly ...	Variegated variety; leaf, very bright green longitudinal stripe, of sulphur colour; fibre very good; edge and keel orange colour.
	Opunake, Native ...	Breaking strain, 79.
	Waitara, Woon ...	Very white and strong fibre.
	West Coast, Heaphy ...	Yields best fibre.
	Christchurch, Armstrong ...	Per centage of fibre, 18·8.
Paretaniwha ...	Whakatane, Native ...	Strong fibre for fishing lines, nets, &c. ; breaking strain, 95.
	Opunake, Native ...	Breaking strain, 83.
	Maungatautari, Bishop Selwyn	A *Tihore.*
	Ditto Mantell ...	Fine kind.
	Waikato, Hutton ...	Yellow, hill flax; strip of leaf ⅛in. broad broke at 42lbs.
Pato ...	Taranaki, Kelly ...	Used for rough purposes.
	West Coast, Heaphy ...	Stiff fibre.
Foitaniwha and *Ngutukaka*	Waikato, Jenkins ...	Or *Paretaniwha* (?) ; good fibre for mill purposes; dark green leaf.
Papu ...	Waikato, Jenkins ...	Yellowish green; brown butts, red edge; good fibre for mill purposes.
Rataroa ...	Taranaki, Kelly ...	Said to be used for best purposes; taper, acuminate, bronzy, green leaf: dark purple keel and edge, fading on the upper side.
	Waiuku, Constable ...	Best *Tihore*; varies from 3 to 8 feet, according to soil; red edge.
	St. John's College, from East Cape	The strongest of all the fibres; beeaking strain, 117.
	Christchurch, Armstrong ...	Per centage of fibre, 21·6.

Name.	District and Authority.	Remarks.
	Waikanae, Native ...	Scarce; very taper, light yellowish green leaf, narrow dark edge.
Ratawa ...	Hauraki, Thames, Bishop Selwyn	A *Tihore*; probably misprinted for *Rataroa*.
Raumoa ...	Taranaki, Kelly ...	Used for rough garments; light green leaf, reddish brown keel and edge; narrower underneath.
	Opunake, Native ...	Breaking strian, 76.
Ruumoa ...	Waikanae, Native ...	Darkish green leaf; broad, red-brown edge on upper side, narrow do. below.
	Taranaki, Bishop Selwyn ...	*Raro*. Requiring to be scraped with a shell.
Rerehape ...	West Coast, Heaphy ...	Yields best fibre; good for cordage.
	Maungatautari, Bishop Selwyn	A *Tihore*.
	Mantell ...	Fine kind.
Rongoinui ...	East Coast and Bay of Plenty, Heaphy	Used for fishing nets and cordage; best fibre for mill purposes.
Taihore ...	Taranaki, Kelly ...	Light green leaf, with wide black edge.
Takaiapu ...	Opunake, Native ...	Breaking strain, 95.
(*Kiapu*) ...	Taranaki, Kelly ...	Fibre very strong; leaf erect, brown edge.
	Opunake, Native ...	Breaking strain, 76.
Tapoto ...	Hursthouse ...	First-rate quality.
	Hawke's Bay, Nairn ...	Leaves narrow, erect, deep purple margin; strong, lustrous fibre, used for sewing threads or weft of fine mats.
	Ditto Locke ...	Sometimes called *Tihore* or *Takiri*; best variety.
	East Coast, Heaphy ...	Also, *Oue*; fibre glossy, silky, but brittle; used for *Kaitaka* mats.
	Opunake, Native ...	Breaking strain, 101.
	Christchurch, Armstrong ...	Similar to *Tihore*; per centage of fibre, 18·7; tapering at the points; edges red.
Tarariki ...	Taranaki, Kelly ...	Used for rough purposes.
	Opunake, Native ...	Breaking strain, 70.
	West Coast, Heaphy ...	Stiff fibre.
	Wanganui, Woon ...	Fine and soft texture, used for *Potas*, or ornamented mats; tapering acuminate leaves; dull, olive green, lighter on the outer side; dark red keel and edge, and keel on the upper side gradually shaded away, forming a dark coloured band ⅛ to ⅜ of an inch broad; 2 or 3 inches of the point of the leaves of the same dark colour.
Tawai kakako	Napier, Native ...	Dark colour when first scraped, but it is put into baskets, and kept to improve its colour.
Tiheru ...	Opunake, Native ...	Breaking strain, 98.
Tihore ...	Taranaki, Kelly ...	Plant of any variety?
	Christchurch, Armstrong ...	Leaves linear, very strong, dark red edge; per centage of fibre 19·8.

Name.	District and Authority.	Remarks.
	Raglan, Native	Breaking strain, 99.
	West Coast, Heaphy	Best fibre.
	Waikato, Hutton	Best variety, cultivated ; strip of leaf ⅛in. broad bore a strain of 48lbs.
Tipuna	Taranaki, Kelly	Used for rough garments.
	Hursthouse	*Tepuna* (?)
Tito-o-moe-wai	Taranaki, Kelly	Used for rough garments.
Tuau	Waikanae	Coarse plant, not used for fine work.
Tuawhitu	Bay of Islands	Fine and soft fibre ; leaf tapering, thin texture, bronzy colour, lined and smeared at the upper end, narrow dark red edge.
Tumara	Waikato, Jenkins	Good fibre for mill purposes.
Turepo	Waikanae	Small yellow variety, grows in wet swamps, and has a white silky fibre; brown edge and keel.
Tutaiwiki	Taranaki, Hursthouse	
Wararika	East Coast, Heaphy	Also, *Mangaeka*—fibre of ordinary character.
Wharanui	Hawke's Bay, Nairn	Soft fibre, used for fine mats.
	Ditto Locke	Next to *Oue*.
	Mantell	Or *Waranui* (?).
Wharariki	Hawke's Bay, Nairn	Weak fibre, only used for kits, &c. ; very broad and tall leaf ; grows in richest soils.
Phormium Colensoi	Taranaki, Kelly	Used for rough garments.
	Waikanae, Native	Never used.
	Heaphy	Stiff fibre.
	Mantell	Also, *Wharaeki*.
	Bishop Selwyn	*Whararipi*.
	Waikato, Hutton	Strip of leaf ⅛in. broad broke at 34lbs.
Witau	East Coast, Heaphy	Poor fibre.

APPENDIX II.

Table A.

SHOWING the NUMBER and VALUE of BALES of PHORMIUM FIBRE and TOW brought to Public Sale in London, from 23rd April, 1870, to 4th April, 1872; showing the Classification adopted by the English Brokers, and the Quantity and Approximate Value of each class.

—	1ST QUALITY. Good to superior.	2ND QUALITY. Fairly Cleaned.	3RD QUALITY. Fully three-quarters dressed.	4TH QUALITY. Half to three-quarters dressed.	5TH QUALITY. Common to rough, half-dressed.	Total.	Tow.
From 23rd April, 1870, to 20th May, 1870	198	189	310	287	66	1,050	...
„ 20th May, „ „ 17th June, „	836	870	462	732	59	2,959	80
„ 17th June, „ „ 15th July, „	36	619	400	999	430	2,484	252
„ 15th July, „ „ 12th Aug., „	817	905	607	1,039	688	4,056	39
„ 12th Aug., „ „ 9th Sept., „	477	745	1,125	863	131	3,341	28
„ 9th Sept., „ „ 20th Oct., „	348	1,227	1,462	1,258	1,144	5,439	53
„ 20th Oct., „ „ 22nd Nov., „	1,031	1,070	2,390	655	493	5,639	455
„ 22nd Nov., „ „ 22nd Dec., „	539	623	247	275	156	1,840	23
„ 22nd Dec , „ „ 24th Jan., 1871	302	236	410	56	67	1,071	207
„ 24th Jan., 1871, „ 21st Feb. „	37	504	955	251	543	2,290	34
„ 21st Feb., „ „ 16th March, „	704	1,796	353	257	493	3,603	198
„ 16th March, „ „ 13th April, „	147	97	96	173	157	670	18
„ 13th April, „ „ 4th May, „	314	368	670	175	39	1,566	69
„ 4th May, „ „ 1st June, „	425	927	634	185	36	2,207	31
„ 1st June, „ „ 29th June, „	305	507	677	199	85	1,773	94
„ 29th June, „ „ 27th July, „	313	530	210	20	16	1,089	299
„ 27th July, „ „ 24th Aug., „	41	471	619	143	...	1,274	128
„ 24th Aug., „ „ 21st Sept., „	117	88	1,021	68	17	1,311	215
„ 21st Sept. „ „ 19th Oct., „	179	458	1,482	297	36	2,452	581
„ 14th Oct., „ „ 16th Nov., „	...	299	658	358	...	1,315	221
„ 16th Nov., „ „ 14th Dec., „	124	497	399	30	...	1,050	190
„ 14th Dec., „ „ 11th Jan., 1872	...	711	683	77	...	1,471	233
„ 11th Jan., 1872, „ 8th Feb., „	30	556	180	122	...	888	21
„ 8th Feb , „ „ 7th March, „	8	553	264	7	...	832	...
„ 7th March, „ „ 4th April, „	342	509	206	...	...	1,057	20

Summary of Table A.

—	1ST QUALITY. Good to superior.	2ND QUALITY. Fairly cleaned.	3RD QUALITY. Fully three-quarters dressed.	4TH QUALITY. Half to three-quarters dressed.	5TH QUALITY. Common to rough, half-dressed.	Total.	Tow.
Total number of Bales	7,670	15,355	16,520	8,526	4,656	52,727	3,489
Total value (reckoning 6 bales to 1 ton)	£43,463	£76,775	£71,587	£35,520	£11,252	£238,597	...
Per centage of total Bales	14·6	29·1	31·3	16·2	8·8	...	...
„ „ in April and May, 1870 ...	18·8	18·0	29·5	27·3	6·3	...	...
„ „ „ „ 1871 ...	20·0	23·5	42·9	11·1	2·5	...	...
„ „ in March and April, 1872 ...	32·4	48·1	19·5	...	...	...	...

The above Table has been compiled from Messrs. M'Landress, Hepburn and Co.'s "New Zealand Flax Circulars," which are prepared in London and sent out by every mail.

Much of the *Phormium* that appears in this Schedule would have been placed in higher classes, and fetched many more pounds per ton, had a little extra trouble been taken in dressing it. For instance, some that was put down as "fairly cleaned," fetched only £22 5s., owing to its "greenish colour," and "having some red ends."

In the Circular of the 12th August, 1870, the English brokers remark:—"It is very important that attention be paid to colour; buyers look particularly to this, and will pay from £3 to £5 per ton more for even parcels of pale colour, than for *Phormium* as well dressed, but dark or green."

"Mixed in colour," "harsh," "wiry," "poor colour," "green and brown in colour," "red ends," "croppy," "coarse," "rough," "much straw" "red colour," and "heeled," are all terms of depreciation used in the market reports. The term "*croppy*" is applied when a portion of the skin is left on the fibre.

The three great requisites seem to be softness, fair cleaning, and good and even colour

Table B.

SHOWING the VARIATIONS in the PRICE of PHORMIUM in the LONDON MARKET during 1870-72.

—	1ST QUALITY. Good to superior.	2ND QUALITY. Fairly Cleaned.	3RD QUALITY. Fully three-quarters dressed.	4TH QUALITY. Half to three-quarters dressed.	5TH QUALITY. Common to rough half-dressed.
From 23rd April, 1870, to 20th May, 1870	£32	£29 10s to £27	£26 to £24	£21 10s. to £20	£16 to £12 5s.
„ 20th May, „ „ 17th June, „	£29 to £30 10s.	£28 to £25	£24 to £22	£21 to £18	£17 to £15
„ 17th June, „ „ 15th July, „	£31	to	£23	£22 10s. to £18	£16 to £12 10s.
„ 15th July, „ „ 12th Aug., „	£31	to £24	£23	£17 to £15	£14 to £12
„ 12th Aug., „ „ 9th Sept., „	£31 10s. to £31 5s.	£26 to £23	£22 5s. to £18	£17 5s. to £14	£13 10s. to £11
„ 9th Sept., „ „ 20th Oct., „	£31 10s to £28	£26 to £24	£22	to £16	£15 to £12 5s.
„ 20th Oct., „ „ 22nd Nov., „	£35 to £30	£28 15s. to £25	£23 to £19 10s.	£18 10s. to £16	£14 10s. to £13
„ 22nd Nov., 22nd Dec., „	£36 10s. to £30	£28 10s.	to £22	£20 10s. to £18	£15 10s. to £14
„ 22nd Dec., „ „ 24th Jan., 1871	£36 15s. to £31 5s.	£30 10s.	to £22 5s.	...	£18 5s. to £16
„ 24th Jan., 1871, „ 21st Feb., „	...	£24 5s. to £23	£22 10s. to £19 15s.	£17 15s.	£16 10s. to £14
„ 21st Feb., „ „ 16th March, „	£34	£28 5s. to £23 15s.	£23 10s. to £19 5s.	£18 5s. to £16 10s	£16 to £14
„ 16th March, „ „ 13th April, „	£34 to £29	...	£22	£19 10s. to £16	£15 to £13
„ 13th April, „ „ 4th May, „	£33 to £29	£27 5s to £24 15s.	£24 to £21	£18 5s. to £16	£15 to £14
„ 4th May, „ „ 1st June, „	£33 to £28 5s.	£26 15s. to £24	£23	to £18	£14 10s.
„ 1st June, „ „ 29th June, „	£30	£27 15s. to £25 15s.	...	...	£16 to £15 5s.
„ 29th June, „ „ 27th July, „	£34 5s. to £30 10s.	£29 5s. to £25 5s.	£25 to £18	£17 10s.	...
„ 27th July, „ „ 24th Aug., „	...	£32	to £24	£21 10s. to £21	...
„ 24th Aug., „ „ 21st Sept., „	£33 10s. to £32	£29 10s. to £29	£26 to £24	...	...
„ 21st Sept., „ „ 14th Oct., „	£31	£29 10s. to £27 15s.	£27 to £23 15s.	£23 to £19 5s.	...
„ 14th Oct., „ „ 16th Nov., „	...	£30 10s. to £30 5s.	£29 10s. to £24 10s	£24 to £22 5s.	...
„ 16th Nov., „ „ 14th Dec., „	£35 5s. to £33	£32 5s to £28 5s.	£27 15s. to £24 15s.	£24 to £22 10s.	...
„ 14th Dec., „ „ 11th Jan., 1872	£36	£34 15s. to £30 5s.	£30 to £26	£25 15s. to £24	...
„ 11th Jan., 1872, „ 8th Feb., „	£36	£33 5s. to £31 10s.	£30 15s. to £27	£26	...
„ 8th Feb., „ „ 7th March, „	£38	£36	to £28 10s.	£27 to £25 5s.	...
„ 7th March, „ „ 4th April, „	£40 to £37 15s.	£36 15s. to £35	£34 5s. to £31 5s.	...	...
Variation of price during the above period	£40 to £28	£36 15s. to £23	£34 5s. to £18.	£27 to £14	£18 5s. to £11
Approximate average price	£34	£30	£26	£20 10s.	£14 10s.

Table C.

STATEMENT of QUARTERLY AVERAGE PRICE during 1868–1871 of FIBRES that compete with PHORMIUM.

FIBRE.	1868.				1869.			
	March 1.	June 1.	Sept. 1.	Dec. 1.	March 1.	June 1.	Sept. 1.	Dec. 1.
Russian Hemp	39s.	36s 3d.	36s.–37s.	39s.–40s.	40s.	36s.	34s. 6d.–35s.	34s.–34s. 6d.
Sisal Hemp	39s.–44s.	...	37s –42s.	38s –42s	40s.–46s.	43s –48s.	44s.–49s.	53s –57s.
Manilla Hemp	44s.–49s.	43s.–53s.	43s.–51s.	42s.–51s.	45s.–51s. 6d.	43s.–51s.	47s.–54s.	53s. 6d –64s.
Egyptian Flax	...	55s.–60s.	52s –60s.	52s.–58s.	54s.–64s.	54s –64s.	55s.–66s.	55s.–66s.
Riga FWPK Flax	56s.–58s.	56s.–57s.	58s.–60s.	60s –61s.	65s.–66s.	61s.–64s.	52s –54s.	51s.–53s.
Italian Hemp	36s. 6d.	...	36s. 9d.	...	41s. 6d.	41s.	42s.	...
Bombay Hemp	...	...	28s.	29s. 6d.	27s.	28s.	...	...

FIBRE.	1870.				1871.	
	March 1.	June 1.	September 1.	December 1.	March 1.	—
Russian Hemp	34s. 6d.	31s. 6d.–34s.	34s.–34s. 6d.	35s. 6d.–36s.	33s.–33s. 6d.	...
Sisal Hemp	55s.–57s.	53s. 6d.–57s. 6d.	47s.–51s.	45s.–51s.	42s.–45s.	...
Manilla Hemp	54s. 6d.–62s.	50s. 6d.–55s. 6d.	51s. 6d.–56s. 6d.	51s.–56s.	51s.–53s.	...
Egyptian Flax	54s.–60s.	54s.–60s.	54s.–60s.	54s.–60s.	48s.–56s.	...
Riga FWPK Flax	48s.–50s.	48s.–50s.	48s.–50s.	48s.–50s.	...	...
Italian Hemp	39s. 6d.	39s. 6d.	...	40s. 6d.	37s.–44s.	...
Bombay Hemp	27s. 6d.	28s.	24s.	...	17s.–23s.	...

Aloe Fibre—Prices not recorded. The range has been from 16s. to 31s., according to quality.

Table D.

SHOWING QUANTITY and VALUE of ROPING and other HEMPS, JUTE, &c., IMPORTED into ENGLAND during the Years 1868, 1869, and 1870, compiled chiefly from the "Trade and Navigation Account" presented to the Imperial Parliament in February, 1871.

—	Total Quantity Imported.			Value (Total).			Average Value per Ton.		
	1868.	1869.	1870.	1868.	1869.	1870.	1868.	1869.	1870.
	Tons.	Tons.	Tons.	£	£	£	£ s	£ s.	£ s.
Roping Hemp	52,810	52,788	55,442	2,080,611	1,940,275	2,063,377	37 0	36 15	37 4
Jute and vegetable substances of the nature of hemp*	110,253	124,803	120,177	1,949,864	2,181,717	2,356,990	17 3	17 9	19 10
Manilla Hemp (included in first line) ...	8,756	4,632	6,467	415,116	245,348	354,589	47 8	52 19	54 16
„ per centage of total roping fibre	16·2	8·7	11·6	...	...	...	...	...	...
New Zealand	...	...	4,033	...	...	95,372	...	...	23·8
„ per centage of total roping fibre	...	...	7·3	...	...	...	...	...	...

* Jute is produced in India at about £5 per ton.

Table E.

SHOWING QUANTITY and VALUE of ROPING and other HEMP, CORDAGE, and JUTE, &c., IMPORTED into the UNITED STATES during the YEAR ending 30th June, 1867.

—	Quantity.	Value.	Average Price per Ton.
	Tons.	£	£ s. d.
Roping Hemps	19,853	601,766	30 16 0
Manufactured Cordage	864	40,686	43 12 0
Total	20,717	642,454	31 0 0
Manilla Hemp } included	15,273	445,847	29 3 0
Do. Cordage } in above	119	5,395	45 7 0
Total	15,392	451,242	...
Per centage of Manilla Hemp and Cordage	73·7	...	...
Jute, Gunny Cloth, &c.	31,992	538,499	16 16 0

Table F.

SHOWING the VALUE of PHORMIUM EXPORTED from NEW ZEALAND up to the end of the YEAR 1864, and the QUANTITY and VALUE of each subsequent year to 31st December, 1870, taken from the Colonial Statistics.

YEAR.	QUANTITY.			ESTIMATED VALUE.			
	Tons.	cwt.	Estimated Number of Bales.	Per Ton.			Total.
				£	s.	d.	£
1865	2	14	17	27	10	0	75
1866	11	3	67	89	0	0	996
1867	126	15	760	33	5	0	4,256
1868	534	0	3,204	15	5	0	8,187
1869	2,027	0	12,162	22	6	0	45,245
1870	5,470	0	32,820	24	2	0	132,578
1871	4,248	10	25,491	21	6	6	90,611
	12,420	2	74,521	...			281,898
Exported prior to 1865	...		...	...			17,909
Total value	...		...	...			299,807

Table G.

EXTRACT from the CENSUS RETURNS showing NUMBER of PHORMIUM MILLS, &c., in NEW ZEALAND during 1870.

—	No. of Mills.	Number of Machines used and Power employed.	Amount of Horse-power.	Hands Employed.		Quantity in Tons manufactured in 1870.
				Male.	Female.	
Auckland	54	94—23 steam, 71 water ...	489	463	29	1,138
Napier	2	5—steam	17	39	2	43
Taranaki	4	11—water	48	63	...	42
Wellington	14	38	108	177	11	508
Marlborough	4	21—8 steam, 13 water and steam	62	127	...	324
Nelson	2	3—2 steam, 1 water	13	14	...	18
Canterbury	24	50—9 steam, 15 water	237	414	...	1,531
Otago	40	66—26 steam, 38 water, 2 horse ...	294	305	18	581
Southland	17	34—7 steam, 10 water	182	104	2	272½
Totals	161	342	1,450	1,706	62	4,457½

APPENDIX III.

MEMORANDA FURNISHED BY COLONEL HAULTAIN ON THE HEMP MILLS VISITED BY HIM.*

THOMAS MACFFARLANE, Henderson's Mill, Auckland, November, 1870.

WAS formerly a large saw mill, driven by water power. Six machines can be kept at work, but only two were in operation. After stripping, the fibre was steeped on wooden floats in the mill pond for two hours and a half, and occasionally beaten with a wooden rammer. Each machine could turn out more than one ton per week. The green leaf was brought by boat from all parts of the Waitemata harbor, at a cost of 20s. to 25s. per ton, according to distance. Men's wages were 5s. a day, and boys' from 1s. 3d. to 2s. 6d. The cost of scutching was 22s. a ton, and of packing and screwing, 22s. 6d; and the total expense per ton, delivered in Auckland, was about £17 16s.

MURRAY, Mauku, near Auckland, May, 1871.

The fibre from this mill is considered as good as any that comes into the Auckland market; its good quality is due to the care taken in its preparation, and to an abundant supply of water for washing purposes. There is a 12-foot water wheel, 5 feet broad, which works one of Price's machines, and the scutching is carried on at another mill a little lower down the stream. After passing through the stripper, the hank of fibre is hung on to a peg in the mill race, where it remains for some minutes. The stripping machine (Price's) has been running for two years, and has required little or no repair; about 26 cwt. of green leaf, per day, can be passed through it. It takes about seven tons of green leaf to one of fibre, and he pays 22s. a ton for it, delivered at the mill; and has to give 30s. a week as rent for the mill site and machinery, and cannot turn out more than one ton per week; so that his flax costs him £19 a ton, delivered in Auckland, where it sells at from £18 to £20; but as he works himself, and is assited by four or five of his children, it gives the family good wages; and the tow, which sells at £5 a ton, is some further profit.

POTTER, Henderson's Mill, near Auckland.

Is not at work at present, as a recent flood has broken the mill dam, and done other damage. Has tried wet-scutching, but did not find it answer, and there is an extra loss of 25 per cent. in hackling, which the rope-spinners object to, although they consider the fibre superior and will pay £3 a ton more for it; but it costs from £8 to £10 a ton to wet scutch as, in addition to the labour, it requires more green leaf. After hackling, as an experiment, there were only 74lbs. left out of 1 cwt. It takes eight tons of green leaf to make one ton of ordinary fibre; if the flax is young it will take more—as much as ten tons. The bleaching requires from four to fourteen days, according to the weather; but the shorter time it is exposed to the sun the better, as the fibre is injured by too long exposure. Instead of wet-scutching, he has now put up a set of stampers, under which the flax is passed, after coming from the stripper, with a flow of water over it, being carried under the stampers by a travelling band.

KELEHER, Waiuku, May, 1871.

Uses a water wheel 14 feet in diameter, and 4 feet broad, which cost him £200, and one of Gibbon's double machines; has also one of Price's, but prefers the former. Carefully washes the fibre in the mill race after stripping, and then soaks it for an hour; bleaches in the sun for about five days in summer, and seven in winter, and finishes with a barrel scutch. All his hands are paid by the day, and he employs twenty for the double machine—eight men, at 4s.; six women, at 2s 6d; and six boys, at 1s 6d; besides two men cutting the flax. He gets £20 a ton for his fibre, delivered in Auckland, which pays all expenses. Flax which was cut eighteen months ago, has now six full grown leaves, and that cut seven months ago has three leaves, besides the centre one. His flax is chiefly from high ground, and is preferred by the rope-spinners on that account.

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* Many of the mills here described have been stopped, or have changed hands since the date of this Report, but, in the absence of further information, it has been thought better to reprint it as it stands.

DUGALD, Queen's Redoubt, Waikato.

Uses the machinery of an old flour mill, belonging to the natives, and has plenty of water, but a limited supply of *Phormium*. Has a machine of his own construction, an improvement on Price's, and can put through 30 cwt. a day, or more; and makes 1½ tons of fibre in the week. Washes in the mill race with the assistance of a small wheel, which is turned by the stream, and beats the flax which is held underneath. Employs only eight hands, and pays the men £1 a week, and the boys 10s and 12s. The green leaf costs about 16s a ton at the mill, and it is chiefly long swamp flax; cartage into town is £1 10s; and the fibre costs him about £16 a ton delivered in Auckland, where he gets from £20 to £22 a ton. Is himself a good mechanic and engineer, so can keep his machinery in good order and repair.

MELLSOP, Waiuku, May, 1871.

Uses water power, and has a wheel 18 feet in diameter, and 2 feet 10 inches broad, but has not sufficient water in summer, nor sufficient green flax to keep the mill constantly going; makes 25 or 30 tons a year, and finds that he must receive £20 a ton for his fibre to pay fair wages. His flax is chiefly from the Karaka hills, and is of better quality than that which grows in the gullies. It takes seven tons of green flax, now nineteen months old, to one of fibre, and he pays 12s a ton for cutting it. He uses one of Dugald's machines, made by McIntyre, of Onehunga, which will put through 30 cwt. a day, and has been six months at work without requiring repairs. Pays men 4s a day, and boys 2s, without food.

REES & GIBSON, Rangitikei, January 1871.

Use steam power and both Price's and Gibbons' stripping machines, but prefer the former, as they clean the fibre better and wear longer; they are, however, more wasteful than Gibbons'. Immediately after having been passed through the stripper, the flax is placed in a wooden vat, and a stream of boiling water is poured on it; it remains soaking for two or three minutes, and is then taken out and rinsed in cold water; then bleached in the sun for four or five days and dry-scutched. The boiling water takes the red colour out of the butts, but does not otherwise improve its appearance or texture. Mr. Rees thinks highly of the wet-scutching process, and will try it when they get over the difficulty of scarcity of water. The limited supply of this requisite, which is one of the chief essentials in profitable flax-dressing, certainly deteriorates the quality of their fibre. The shorter leaves are separated into bundles by the boys who take the fibre away from the stripper, and it is packed separately. Mr. Rees finds that most of the fourth pair of leaves are unfit for stripping, and that even some of the third are defective and have to be rejected. He has tried a small quantity of the centre and immature leaves, and the fibre is fine and of good colour, and has considerable strength, but it cannot be procured in any quantity. He wished that some Natives should, by way of experiment, prepare after their own fashion a small quantity of fibre from the flax leaves that he was using at his mill, but after looking over the whole bundle, about eight tons, they declared that there was none suitable for their purpose, so particular are they in the selection of leaves.

MUSSON, near Wanganui.

Has a twelve-horse power steam-engine and abundance of water, but he has to pay a very high price for the raw material. He gives the owner of the ground on which he cuts the leaves, 12s a ton, and it costs him 10s a ton for cutting, and another 5s for carting to the mill; so that, assuming he requires 6½ tons of green leaf for one of fibre (and it can hardly be less, though he only estimates 5½ tons), the raw material stands him in £8 15s 6d, which at the present price of the manufactured article can hardly leave him a profit, although he turns out a particularly good sample, mainly due to his wet-scutching, which softens the fibre and gives it a good colour. It is not left out on the bleaching field for more than three days in fine weather, being once turned in that time. He has two stripping machines at work, one of Price's, and the other, Fraser and Tinne's. He considers that the latter wear better, but that Price's dresses the flax more evenly. He employs nine men and three boys for the two machines, and pays the latter 6s and 7s 6d a week besides their food. He uses a beam 36 feet long and 18 inches square at the larger end as a lever to press his bales, and manages, to get 4½ cwt. of fibre into a bale measuring 3 feet square and 5 feet long. Plants that were cut quite down twelve months ago, have thrown up several leaves 5 and 6 feet long.

RITCHIE, Wanganui.

Uses the engine of a steam-threshing machine, and one of Price's strippers, which he considers the best that are made. The green leaf only costs him 13s a ton delivered at his mill; but there is a scarcity of water for washing purposes, otherwise he would use a wet-scutcher, believing that that process materially improves the fibre besides reducing the time necessary for bleaching from fourteen to four days. He has three varieties of flax growing on his land, and plants that had been cut five months previously had thrown up fresh leaves five feet long. The best variety strips more easily than the other kinds.

SCRIVENER, Wanganui.

Produces a fibre of superior quality, and took the first prize at the Wanganui Flax Show. The reason is obvious; every part of the process of manufacture is conducted with special care. All damaged leaves are rejected, and the larger ones are split before they are passed through the machine; they are also cut high up, so that the coarse and discoloured portions of the butt are not used. He works only on a small scale, and has but an ordinary three horse wheel for driving purposes. With the assistance of one man to cut the flax, and a lad to drive the horses, he and his three sons manage the whole of the operations, and can turn out 2 cwt. of fibre per day, and as he can readily get £20 a ton for his fibre in Wanganui, it pays him very well. In feeding his horses, he mixes the strippings from the flax leaves with their oats, and they eat it greedily. He uses one of Price's machines, which he considers the best he has seen. Had he more driving power, he would not think it necessary to split the leaves, and would wet-scutch if he had plenty of water. There are several varieties of flax in the neighborhood, some of which are more easily stripped than others, but they are used indiscriminately

GROVER, Wanganui.

He has a small steam engine, and one of Price's machines, and adopts the ordinary process of washing, bleaching, and dry-scutching. He has not sufficient water, or would try wet-scutching.

CUMMINS, Wanganui.

Has also a small steam engine, and one of Price's machines, which he finds to work satisfactorily. After stripping, he soaks the fibre in warm water. at about 90°, and then bleaches and dry-scutches in the ordinary manner. Has tried boiling water, but finds that it hardens the fibre.

OPUNAKE, Taranaki, January, 1871.

There are two flax mills at Opunake, belonging, one to the Cape Egmont, and the other to the Opunake Company; both companies have extensive flax fields, leased from the Natives. The sites for their mills are excellent, with abundance of water for motive power, and for washing purposes. Considerable capital has been expended, and the buildings and drying grounds are good and sufficient; in fact, there are few other mills in the North Island equally good, and possessing such natural advantages; and Opunake Bay is a convenient and safe shipping place. The fibre turned out from the Cape Egmont mills is the better of the two, because greater pains are taken in scutching; but in neither is sufficient care taken to reject old and damaged leaves; consequently the sample is not so equal and good as it ought to be, and it can hardly realize a fair price in the London market. The green flax on this part of the coast is much damaged by a small "looper" caterpiller, about an inch in length, which attacks the under side of leaf, and eats quite through the fibre, in patches from a-half to two inches long and a-quarter of an inch broad. As these patches are numerous, the fibre is cut into short lengths, so that in scutching there is a great loss in tow. The plants growing in sheltered places were the most damaged as the insect cannot so readily attach itself to leaves that were kept in motion by the wind. The caterpillars appear to have come to their full growth about the month of December, and they must have been very numerous at that time. The Opunake Company use Price's, Gibbon's, and Murray's machines, and consider the small ones made by the first, preferrable to any others. After stripping, the flax is washed by hand, and then floated down the tail race, at the end of which men are stationed to take up the flax, which is soaked for an hour in a trough, through which the water flows freely, and is then kept on the drying ground for twelve or fourteen days in the summer season, and for a longer period in the winter. The color is good, and it would be above the average if damaged leaves were rejected. The plant of the Cape Egmont Company is first class, and has been erected at considerable outlay. A sixteen feet water wheel, eight feet broad, set upon masonry supports, works smoothly, and puts in motion four of Price's smaller machines, and one of Fraser & Tinne's, besides two scutchers. After stripping the flax is well washed by hand in the mill race, and then placed in cradles in the water for a couple of hours, being pressed down and trodden on by one or two men, so as to squeeze out as much gum, &c., as possible. It is intended to use wooden stampers for this purpose, and the colour and softness of the fibre would be much improved by this, or by any other beating process. Twenty-four hands are employed, the men receiving 5s., and the boys from 1s. 6d. to 3s. per day. A few Natives are at work, but European labour is preferred, as the former cannot be depended on for regular, steady work. About one ton and a-half of green leaves can be passed through each machine daily, and it takes at least seven tons of leaf to produce one of fibre. The manager, Mr. Kelly, thinks that Price's machines are not strong enough, or sufficiently large; and that it would be an advantage if they could be set from the back, so that they might be adjusted by the engineer when necessary, without stopping the machine.

NELSON BROTHERS, Napier, 29th May, 1871.

The mill is ten miles from Napier, with about fifty acres of good flax swamp. It is worked by steam power, and two of Price's machines are kept going; water is abundantly supplied from two artesian wells, 57 feet deep. A constant flow is kept on the flax whilst passing through the stripper, and it is then put between wooden rollers, and washed in tubs in which fresh water is continually pouring, so that much of the gum or cement is separated before it is put out to bleach It remains out for a week or more, according to the weather, and it is then scutched by a barrel scutch, and the uncleaned tips are cut off by a knive, which is fixed to the scutcher at one end of the beaters. Great care is taken in sorting and cutting the leaves, which are from three to five feet long, only, and these are separated into bundles of the three sizes, and the edges and keels are stripped off before passing through the machine. The leaves now used are of twelve months growth; the flax was cut fifteen months since, the three centre leaves of each set being left. Within that time there has been a fresh growth of four full-sized leaves to each set; and at the second cutting, the three centre leaves were again left, the four outer ones only being taken, and of these the two first were frequently rejected, as too much spotted and decayed for manufacture, proving that, under these conditions, after a second years growth, the leaves have passed their prime and begun to decay. This ground was formerly very wet, but from draining and treading it is now comparatively dry, and the growth of the plant is much improved, for the younger leaves are invariably longer, and more luxuriant than the older ones. This field of Mr. Nelson's affords an excellent opportunity for further observations, as the plants are most carefully cut, and it is under the constant superintendence of the proprietor. From those already made here, and in other *Phormium* fields, we may conclude that each set from an established vigorous plant, in suitable soil will yield four good leaves for manufacture every year. Mr. Nelson pays 12s. a ton for cutting the leaves, and estimates that 5½ tons give him a ton of fibre; and he prepares about 1 ton a week, with 5 cwt. of tow. He pays his men £1 a week, and his boys 7s., besides their food; and estimates that the total cost (not including wear and tear, his own superintendence, interest on outlay, &c.) is about £15 a ton for scutched *Phormium*, besides 12s. for carting into Napier. He has been hackling some three tons of fibre, after scutching, and has produced a beautiful sample; but half of the fibre passes into tow, and he calculates that from 12 tons of green leaf he gets—

1 ton of fibre costing	£23	0	0
1 ton of hackled tow, valued at	12	0	0
5 cwt. of scutched tow	2	0	0
	£37	0	0

If the tow is worth the money above stated, the fibre would yield a good profit, as it is perfectly clean and uniform. Mr. Nelson sends a bale of this hackled fibre for the exhibition at Wellington.

Stonyer & Co., Kaiapoi, Canterbury, June, 1871.

Use a water-wheel of fourteen feet diameter, and the same number of feet broad, which works two double stripping machines and one scutcher, and raises water sufficient for washing the fibre. It is about equal to a twenty horse-power steam engine, and therefore could keep more machines at work. At night it drives a flour mill. They have tried Williams,' Howarth's and Barnes' machines, but they did not work so well as Anderson's; Barnes' was constantly blocking up. They have plenty of flax in their neighborhood, and it costs them 10s. a ton for cutting. It is passed through two of Anderson's strippers, one fixed below the other, and the two are fed by one operation, the leaf passing from one machine to the other without a second handling. A stream of water flows through the strippers, falling into a shoot below, into which the fibre drops, and is carried along some twenty feet, where it is picked up by a boy, put into hanks, and hung on hooks fastened to a pole that stretches across the mill stream, and remains there for an hour. It is then put out on lines to dry, and in summer will bleach in twenty-four hours, but in winter it will take as much as a week. The second stripper is of great advantage, when sufficient power can be easily obtained, for this fibre is soft and of very good colour, and took the first prize at the exhibition of the Canterbury Flax Association in 1870. The expense of preparation is not increased, and fibre baled, and covered with cloth, ready to be shipped, could be produced at this mill for £16 a ton (exclusive of interest, wear and tear), as the raw material is easily obtained, and the water is abundant, and wages are moderate. It takes 7½ tons to produce a ton of fibre from one machine; and the various expenses are as follows:—

7½ tons of green leaf, at 10s.	£3	15	0
1 feeder, 7½ days, at 4s.	1	10	0
2 washers, „ at 4s. 6d.	3	7	6
2 men taking and bringing in from field, at 5s. ...	3	15	0
Baling and pressing	6	10	0
Covering	1	0	0
Total ...	£13	17	6
Scutching	2	0	0
	£15	17	6

They have sold it to Lennan, for rope spinning, at £27 and £30 per ton. *Phormium* cut on the road side in December, 1869, and December, 1870, has now (June, 1871) four or five leaves to each set, and is four and five feet high. They use an American lever cotton press for baling, which is very simple, and more powerful than a screw. White New Zealand rope will barely last a week in their "Californian pump," always wet; but when prepared with whale oil, it will last several weeks, though constantly under water.

Benn & Walker, Kowai Mills, Leithfield, Canterbury.

Have two mills, worked by steam power; one engine of 18 working up to 25 horse power, and driving four of Price's large machines, two water-scutching wheels, and three arm-scutchers; the other, of 6 horse power, working up to 8 and driving two of Price's large machines, and a water-scutcher. They have tried Howarth's, Anderson's, and Williams' machines, but prefer Price's. Cutting the green leaf costs 12s a ton After passing the stripper, through which a flow of water passes, it falls on to a travelling band or table, from which one expert man can pick up from the four machines (but an ordinary boy cannot pick up from more than two). It is then wet-scutched under a barrel scutch of 4 feet diameter, with 2½ inch beaters of rounded wood, revolving at a rate of 250 revolutions per minute. It is then soaked for twenty-five minutes, and bleached a fortnight or more, according to the weather. It is dry-scutched by an arm or Irish scutcher. The quality of the raw material is good. Of one variety it requires only 5½ tons for one ton of fibre; of another variety, it requires as much as 6¾ tons of green leaf. The former is equal to any *tihore Phormium* that grows in the North Island. The other variety grows in the same locality, and is more luxuriant, reaching a height of 10 or 12 feet, and is of a darker green color. The best *Phormium* grows on a black peaty soil, with shingle about 2 feet from the surface, and is about 7 feet long. The *Phormium* can be cut every year if the centre leaves are not taken; 30 cwt. of green *Phormium* can be passed through each machine during the day. Sold 100 tons at £20 and £21 15s. to go to Boston, America. The actual cost of preparation is about £18 a ton, with 25s. cartage to Lyttelton. The six machines employ fifty men and boys, and turn out 6 and 7 tons a week The cost of the steam engine is £3 per ton. 113 lbs of fibre lost 25 lbs in dry-sutching (20 lbs of tow, and 5lbs waste); 20 lbs of tow, when hackled, yielded 15 lbs of fibre, and 5 lbs of tow. Floor mats made from the fibre have been in use at the hotel at Leithfield for two years, and are still in good condition.

Ashley Gorge Mills, 38 miles from Christchurch.

Not visited, but Mr. DeBourbel states that they have a 20 horse-power steam engine, working up to 30, which drives four of Price's, one of Fraser & Tinne's and three of Anderson's machines, besides three dry-scutchers, and a small turning lathe; about 120 hands are employed, including wood-cutters for fuel for the engine. It requires 6 tons of green leaf to one of fibre, and the *Phormium* is passed through the stripper with a flow of water, and is taken away on a travelling band or table, two boys being able to pick up from the eight machines. It is washed by hand, and soaked for one hour, and scutched with an arm-scutcher. The cost of the preparation may be set down as follows :—

6 tons of green leaf, at 13s.	£3	18	0
Stripping, soaking, washing, bleaching, and scutching	8	5	0
Pressing, baling, hooping and covering	1	8	0
Steam engine	3	0	0
Delivery in Lyttelton	2	0	0
	£18	11	0

Besides wear and tear, and interest on capital.

Blueskin Mills, Dunedin.

Use one steam engine of 16 horse-power, working up to 23, and a water-wheel of 8 or 9 horse-power. Also, six of Kincaid and McQueen's machines (improved), making 160 revolutions per minute, each of which will pass through 32 or 33 cwt. per day of green leaf; it takes 6½ or 7 tons of leaf to produce one of fibre; and the leaf costs 18s. per ton, delivered at the mill. The owners are introducing a wet-scutcher, and also have a pair of iron rollers for pressing out the moisture after scutching. The water-scutcher will make 110 revolutions, and the dry-scutcher 300 per minute. The rates of wages vary from 10s. to £1 16s. per week. The machines can turn out 2¾ tons of fibre per week, at the following cost :—

Engine and stripper	£9	16	0
Washing	2	10	0
Bleaching	6	15	0
Scutching	5	15	0
Firewood	1	13	0
Green leaf	13	13	7
Total for 2¾ tons	£40	2	7

Or, per ton	£14	11	0
Carting to town	0	18	0
Oil, &c.	1	0	0
	£16	9	0

Besides interest on capital, wear and tear, &c. Drying ground not good.

MILLER, Silver Stream, near Dunedin.

Has a water wheel 14 feet by 4, and drives one of Price's machines. Pays 12s. a ton for the green leaf, delivered at the mill, and requires 6½ tons for one of fibre. Washes by hand, and turns out only half a ton a week, as the mill is not kept constantly at work Pays from 5s. to £1 a week for boys and men, besides their food, and gets £19 a ton in Dunedin for his fibre, for rope-spinning; paying 22s. a ton for carting it in. He takes great pains in the different processes, and makes a very good sample.

SOUNESS & Co., near Dunedin.

Have an 8 horse-power steam engine, which drives two or three Kincaid and McQueen's strippers. They pay 17s a ton for the green leaf, and require 7 or 8 tons for one of fibre The *Phormium* is hand-washed, and requires three weeks to bleach and dry, when it is passed through a barrel-scutcher. Wages vary from 10s to £1 a week, with food for boys and men; and they can produce two tons of fibre a week, when keeping two of the machines constantly going

CAMPBELL, Ashburton Mills, near Dunedin.

Use a water-wheel 30 feet by 2, and one of Kincaid and McQueen's, and another of Barnes' stripping machines, which can each put through 30 cwt. of leaf per day. Employs only boys at the mill, besides the grown up men of the family. Pays 13s. a ton for the green leaf, and requires 7 tons to make one of fibre; washes in boxes, and supply of water is limited. After bleaching in the sun, it is put through an arm-scutch, the imperfectly stripped ends having first been cut off. The cost of preparation is between £13 and £14 per ton, including 10s. cartage to Dunedin.

SEYMOUR, Wairau, 21st December, 1870.

There are very large *Phorminm* fields in the valley of the Wairau, and it is profusely in flower this year. The settlers only recognise one species, though it varies in size and colour of the leaf according as it grows in wet or drained land. Mr. Seymour states that he preferred the shorter and yellower variety, as it passed more easily through the machine, and supplied an equally strong and a better looking fibre. His mill is not at work at the present time, but it is likely that he will soon resume operations. His buildings and plant are very complete, but the supply of water for washing is very deficient, and he will never produce a good sample until this want has been provided for. He has used Price's, Anderson's, and Mills' stripping machines, but greatly prefers the first, as working better, and being less liable to get out of order. He has had one of them in constant use since March, 1870, that has never required repair. Has made 80 tons of fibre at a cost of £20 per ton, including interest on capital. It would cost 30s. a ton extra to split the leaf. The *Phormium* plants that were cut five or six months ago have sent up several good leaves, three or four feet long, and will be ready to cut again by the time the twelve months has expired. The fans that had thrown up a flower stalk have invariably died away after having been cut; and the fan that produced seed last year, whether cut or not, has died this season. Whether this is constant should be carefully noted in other *Phormium* fields.

MR. HATAWAY is dressing *Phormium* at his mills on the Wairau River, close to the ferry. He prefers Anderson's machines, and advertises them for sale; but the fibre, as it comes from the strippers, is very insufficiently cleaned. He has, however, abundance of water for washing purposes. Mr. Ninnis, the manager, has a seed bed, in which were some young *Phormium* plants, four and five inches high, which were four months old; these had been sown in September. He had planted in every other month of the year without success.

MR. HOWLAND, about two miles higher up the river, was about commencing work. He has magnificient water-power, and a centrifugal pump supplies him with volumes of water for washing the *Phormium.* He uses Anderson's machines for stripping, and has, besides, a stamping machine of his own invention, under which the *Phormium* is passed by an endless band immediately after coming from the stripper, whilst a stream of water flows over it. I have no doubt that his fibre will be cleaned in a very superior manner; but one set of stampers will not be able to keep pace with his five or six stripping machines. He uses a peculiar scutcher, with toothed or scolloped beaters.

APPENDIX IV.

CLASSIFICATION OF THE VARIOUS MACHINES USED IN THE PREPARATION OF *PHORMIUM**

Class I.—Where the leaf is operated on in its natural state.

Sub-Class A.—*By Percussion on Elastic Metallic or other Surfaces.*

1. Metallic beaters are fixed to a drum, and form right and left angles to the axis of rotation; the drum revolves at a high speed, and the beaters operate on one side of the leaf on revolving metallic rollers, the journals of which are supported by elastic bearings. Price's machine is a type of this class.

2. Metallic beaters are fixed to the face of a drum and form right and left angles to the axis of rotation; the drum revolves at a high speed, and the beaters operate on one side of the leaf on a metallic plate supported by elastic bearings. Fraser & Tinne's machine is a type of this class.

3. Metallic beaters are fixed to the face of a drum parallel to each other and at an angle to the axis of rotation; the drum revolves at a high speed and operates on one side of the leaf, on a metallic bar supported by elastic bearings. Mr Gibbon's machine is a type of this class.

4. Metallic beaters parallel to each other are fixed to pairs of arms radiating from a shaft which revolves at a high speed, and by means of two sets of revolving beaters both sides of the leaf are operated on, on a series of narrow metallic bars supported by elastic bearings. Booth's improved machine is a type of this class.

5. Metallic beaters parallel to each other are hung loosely between the outer edges of dics fixed on a shaft which revolves at a high speed, the loose beaters operate on one side of the leaf on metallic rollers, the journals of which are supported on elastic bearings. J. H. Nodding's machine is a type of this class.

6. Metallic beaters are fixed parallel to each other and to the axis of rotation on the face of two drums revolving together at a high speed and operating on both sides of the leaf; the beaters of one drum striking on the space between the beaters of the other alternately. Pownall's machine is a type of this class.

7. Metallic beaters parallel to each other are fixed to pairs of arms radiating from a shaft which revolves at a high speed, and by means of two sets of such revolving beaters, both sides of the leaf are operated on on india-rubber rollers. Booth's patent is a type of this class.

Sub-Class B.—*By Percussion on Non-elastic Metallic or other Surfaces.*

1. Metallic or wooden stampers, with or without springs, are caused to fall on the leaf on a bed of wood or metal, fixed or moveable with or without water. Purchas and Ninnis', Franz Scherff's, and Howland's machines are types of this class.

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* A description of most of the different patents will be found at pp. 50, 55 of Report of Flax Commission, 1870, (Parl. Papers, D. 14).

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